Iron and Steel Engineer

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J. F. KELLY, *Editor*

CONVENTION NUMBER

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Association of Iron and Steel Electrical Engineers

EXTEND A CORDIAL INVITATION

TO ATTEND THEIR

27th ANNUAL CONVENTION

AND

IRON AND STEEL EXPOSITION

JUNE 15-16-17-18-19, 1931

CLEVELAND PUBLIC AUDITORIUM

CLEVELAND, OHIO

TECHNICAL SESSIONS 9:30 A. M.

Electrical Engineering Division
Combustion Engineering Division
Lubrication Engineering Division
Safety Engineering Division
Wire and Wire Products Association

EXPOSITION HOURS

Monday	1:30 to 5:30 P. M.	Evening 7:00 to 10:00 P. M.
Tuesday	1:30 to 5:30 P. M.	Evening not open
Wednesday	1:30 to 5:30 P. M.	Evening not open
Thursday	1:30 to 5:30 P. M.	Evening 7:00 to 10:00 P. M.
Friday	9:30 A. M. to 5:30 P. M.	Evening 7:00 to 10:00 P. M.

OFFICIAL CONVENTION HEADQUARTERS—HOTEL STATLER, CLEVELAND, OHIO

Association of Iron and Steel Electrical Engineers Convention and Iron and Steel Exposition

JUNE 15 - 16 - 17 - 18 - 19, 1931

Technical Sessions, Cleveland Public Auditorium — **CLEVELAND, OHIO** — ***Iron & Steel Exposition, Cleveland Public Auditorium***

Convention and Iron and Steel Exposition Committees

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Monday Evening Informal Reception

Members, Exhibitors and Guests

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Thursday Evening Formal Reception

F. O. SCHNURE, *Chairman*

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C. L. Collens, W. D. Sayle, C. O. Kennedy, J. Farrington, J. D. Donovan
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P. C. Clark, F. D. Egan, J. A. Voss, W. Seely, C. C. Pecu

LIST OF EXHIBITORS

IRON AND STEEL EXPOSITION

CLEVELAND PUBLIC AUDITORIUM **CLEVELAND, OHIO**

JUNE 15 - 16 - 17 - 18 - 19, 1931

Exhibitor	Booth No.
Air Reduction Sales Co.	167
Ajax Electrothermic Corp.	120
Ajax Flexible Coupling Co.	103
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American Air Filter Co.	201–202
Anaconda Wire & Cable Co.	84
Appleton Electric Co.	143
Automatic Reclosing Circuit Breaker Co.	168
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Bailey Meter Co.	130
Bartlett Hayward Co.	121
Benjamin Electric Mfg. Co.	92–93
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Brown Instrument Co.	181–183
Bull Dog Electric Products Co.	114
Burndy Engineering Co.	196
Carboloy Company, Inc.	47–48
Century Electric Co.	157
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Cleveland Crane & Engineering Co.	128–136
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Cleveland Switchboard Co.	113
Cleveland Worm & Gear Co.	115
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Exhibitor	Booth No.
Lincoln Electric Co.	104-105-118-118x
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PROGRAM

THE WIRE ASSOCIATION

TECHNICAL SESSIONS
JUNE 16, 17, 18, 1931
CLEVELAND PUBLIC
AUDITORIUM

IRON AND STEEL EXPOSITION
JUNE 15, 16, 17, 18, 19, 1931
CLEVELAND PUBLIC
AUDITORIUM

CLEVELAND, OHIO

PROGRAM—TUESDAY, JUNE 16th, 1931, 9:30 A. M.

"History of Wire Industry," by Kenneth B. Lewis, of the Morgan Construction Company. A paper on the historical side of the wire industry showing the changes and developments in production methods.

"Heat Treating," by Joseph A. Doyle, Vice President of the W. S. Rockwell Company.

"Bright Annealing and Galvanizing," by W. H. Spowers, Jr., Consulting Galvanizing Engineer.

"Rust Protection of Wire Products with Cadmium,"by Clayton M. Hoff, Engineer, Grasselli Chemical Company.

The Story of Steel—A motion picture showing the manufacture of rods, rails, etc., together with inspection, cutting and finishing methods.

Steel Wire Products—A motion picture showing the manufacture of steel wire products, the preparation of rolling, drawing of wire, galvanizing of wire, making wire fence; winding wire and cold rolling of flat stock. Also shows the methods of heat treating, annealing, pickling, etc.

PROGRAM—WEDNESDAY, JUNE 17th, 1931, 9:30 A. M.

"Wire Mill Management," by E. G. Brown, Asst. Factory Manager, the U. S. Rubber Company, Bristol, R. I. A paper on the readjustment of manufacturing costs to meet changed business conditions.

"Wire Mill Cost Accounting," by L. D. Granger, Assistant to the Vice President and Chief Metallurgist of the Wickwire-Spencer Steel Company, New York, N. Y.

"Lubrication," by R. T. Kline, Lubricating Engineer, the J. T. Robertson Company, Syracuse, N. Y.

"Lubrication and Application of Tungsten Carbide Dies," by C. R. Longwell, Engineer, the Carboloy Company, Newark, N. J.

U. S. Government motion picture entitled **"Submarine Cable Laying."** *This picture will show in detail the process of production of submarine cable and its actual use under working conditions. The production man will get an excellent idea of the necessity for a rigid adherence to specifications in manufacturing such cable.*

PROGRAM—THURSDAY, JUNE 18th, 1931, 9:30 A. M.

"Some Phases of Insulating Work," by P. O. Reyneau, of the Western Electric Company, New York, N. Y.

"Manufacture of Insulated Wire & Cable," by J. W. Hackett of the Okonite Company, Passaic, N. J., accompanied by a motion picture film showing manufacturing processes of that firm and the machinery and methods used in the insulating of electric wire and cable.

"The Story of the Fabrication of Copper"—A motion picture prepared by the American Smelting & Refining Co., showing rolling of copper rods and drawing of wire: methods of annealing, pickling, washing and drying; method of coiling, cooling and gauging; making of trolley wire, winding wire; stranding and twisting into cables: and testing methods.

"The Manufacture of Wire Rope,"—A motion picture of the technical processes of the John A. Roebling's Sons Company, Trenton, N. J., showing the steel mills, the blooming and rod mills, the wire mills, heat treating and cleaning methods and finally the huge machines fabricating the wire into many different kinds of rope.

A most interesting feature will be the U. S. Signal Corps official war film showing the use of wire of various kinds under actual combat conditions in the World War. This will be shown Wednesday afternoon as a separate exhibit. All production men should see this film as it will show the reason for definite rigid specifications for the various kinds of wire which they use.

Mr. F. O. Schnure, Electrical Superintendent, Bethlehem Steel Co., Sparrows Point, Md., President of the Association of Iron and Steel Electrical Engineers for the year 1930-1931.

Prodigal Power

By F. O. SCHNURE*

Electric Power finds its way into every ramification of our industry. It turns alike the multi thousand horsepower motors on the mills and the one thousandth horsepower motor on the meter. It substitutes for the sun both for light and heat. Its vacuum tube sent rays bridge space. It is always straining at the leash. We who would mould and control this motive must guard against prodigality.

The ore bridge, the car dumper, the skip hoist have replaced the hand shovel, the basket and the wheelbarrow in handling raw materials.

The ladle and soaking pit cranes, the charger, the magnet, the motor driven dolomite thrower, the power manipulators, and others, some controlled by the vacuum tube sent ray, have replaced the back breaking labor of the past, in handling processed materials.

The powerful, easily controlled continuous mills of today have grown from the ancient forge where sheets were hammered out by hand.

Steel, once cut by chisel and file is severed by the power shear and carved by the oxygen flame.

Always, after the first flush of enthusiasm, over some newly born machine or process, comes the inevitable check up on input versus output.

Friction, is perhaps, the pathway where most prodigal power travels. What is being done to level off this road in our industry? To overcome friction, first, tallow was applied to wood, then metal to metal, again, alloy to metal. Now ball and roller bearings in motor and machine, proper application of lubricants, gear and shaft design are some of the forces engaged in reducing the toll of friction.

Mis-application is another road traveled by prodigal power. The use of D.C. motors where constant speed, A.C. motors are more efficient, the use of larger A.C. motors than warranted by the load with resultant loss through poor power factor, the use of induction where synchronous motors can be applied, the use of low voltage where high voltage motors are more efficient, are some of the lanes leading to this road.

Generation and Transmission are parallel paths often traveled by prodigal power. Either of the above at too low a voltage represents a serious loss. The earlier accepted transmission voltage of 2300 volts for plant distribution has given way to 6600 volts and for plants widely spread out and with heavy loads, 22,000, 26,000 volts and higher, are practicable. The operating troubles on a well installed 26,000-volt line are no more than the 6600-volt line and the installation and losses are proportionally lower.

Our Association is a forum for evolving and distributing the ideas to harness this prodigal. The program at our Cleveland Convention is well calculated to stir your interest and enthusiasm.

The new trend in office, factory, and health building is promoted by the paper on the health ray lamp.

The "Twin Motor Drive" is 1930-31's super contribution to the Iron and Steel Industry. In one swoop it has eliminated the power consuming and ever wearing pinions between the motor and mill. The thesis on Motor and Control equipment for Cold Strip Mill Drives is appropriate to the times.

Combustion is represented by a debate between Electrical versus Mechanical control devices. The Steel Mill Electrical Man will watch this discussion with great interest. He has often felt this centipede had more legs than necessary.

Lubrication, the latest field of investigation in our Association presents a hundred new ideas in a field that is as old as the hills.

Electric Heating and Melting in well defined cases proves economical because of the reduction in labor, stack and combustion losses, as well as a reduction in oxidation losses and an improvement in quality.

What are the next steps in combating prodigal power? The further development of the vacuum tube for power and control transmission; the alloyed structure giving lighter weight, greater strength and longer life; automatic operation increasing the productivity of the human factor. These are a few of the many vital problems for the Iron and Steel Electrical Engineer.

* President, A. I. & S. E. E.

Monday, June 15, 1931

Hotel Statler

9:00 A. M. Registration, Mezzanine Floor, Chairman, J. A. Clauss, Ch. Engr., Great Lakes Steel Co., Detroit, Mich.

9:30 A. M. Business Session, The Major Ball Room. Membership Invited. Chairman, F. O. Schnure, Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.

Technical Sessions, Major Ball Room. General Chairman, F. W. Cramer, Chief Elec. Engr., Republic Steel Corp., Youngstown, O. Secretary, W. H. Burr, Elec. Supt., Lukens Steel Co., Coatesville, Pa.

10:00 A. M. "Electrical Developments in the Iron and Steel Industry" by W. H. Burr, Elec. Supt., Lukens Steel Company, Coatesville, Pa.

10:45 A. M. "Research Covering Alternating Current Arc Welding" by Grover A. Hughes, Elec. Engr., Truscon Steel Company, and R. C. McBride, Chemist, Truscon Steel Company, Youngstown, Ohio.

11:45 A. M. "Standardized Symbols for Control Apparatus" by Special Committee on Control Apparatus.

Safety and Electrical Engineering Divisions, Technical Session, Cleveland Public Auditorium, J. A. Voss, Chairman, Managing Safety Director, Republic Steel Corp., Youngstown, O. Secretary, J. F. Hunter, Safety Engineer, Carnegie Steel Company, Pittsburgh, Pa.

2:00 P. M. Symposium.

"Controlled Conditions" Plant by H. E. Stitt, Chief Engineer, The Austin Company, Cleveland, Ohio.
"The Application of Health Lamps to the Iron and Steel Industry with Respect to Health and Efficiency" by M. J. Dorcas, National Carbon Company, Cleveland, Ohio, and L. C. Porter, Engineering Department, Nela Park Works, General Electric Company, Cleveland, Ohio.

7:00 P. M. Official opening of the Iron and Steel Exposition—Cleveland Public Auditorium.

50,000 square feet of space devoted to an Exhibit of Developments in Equipment and Apparatus used in the Iron and Steel Industry.

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OFFICIAL
CONVENTION and IRON
CLEVELA
Aus
Association of Iron and S
JUNE 15-16-1

9:00 P. M. Informal Reception for Members, Exhibitors and Guests—Cleveland Public Auditorium. J. D. Donovan, General Chairman, Mechanical and Electrical Superintendent, Republic Steel Corporation Plants at Massillon and Canton, Ohio.

You are cordially invited to attend and renew your acquaintanceship with your friends of the Steel Industry. Membership cards and Exhibitor's Passes admit.

Tuesday, June 16, 1931

Technical Sessions—Cleveland Public Auditorium

Bearings—General Chairman, J. H. Van Campen, Chief Engineer, Republic Steel Corp. Plants, Youngstown District, Youngstown, Ohio. Secretary, G. R. Carroll, Elec. Supt., Jones & Laughlin Steel Corp., Aliquippa, Pa.

10:00 A. M. Report—Special Committee on Bearings, by F. D. Egan, General Chairman, Special Committee on Bearings and Elec. Supt., Bethlehem Steel Co., Lackawanna, N. Y.

10:30 A. M. Mill Drives.
General Chairman, A. C. Cummins, Elec. Supt., Carnegie Steel Co., Duquesne, Pa. Secretary, James Farrington, Elec. Supt., Wheeling Steel Corp., Steubenville, Ohio.
"Motor and Control Equipment for Cold Strip Mill Drives" by F. Mohler, Industrial Engineering Department, General Electric Co., Schenectady, N. Y.
"Twin Motor Drive" by R. H. Wright and H. E. Stokes, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

9:00 P. M. Boat Excursion—Lake Erie.
Admission by card only.

Wednesday, June 17, 1931

Technical Sessions, Electrical Engineering Division

Cleveland Public Auditorium

General Chairman, J. J. Booth, Elec. Supt., National Tube Co., Gary, Ind. Secretary, S. L. Henderson, Elec. Supt., Central Furnaces, American Steel & Wire Co., Cleveland, Ohio.

PROGRAM
AND STEEL EXPOSITION
ND, OHIO
ices
eel Electrical Engineers
7-18-19, 1931

10:00 A. M. "A Description of the Electrical Installations Located at the Fairfield Plant of the Tennessee Coal, Iron & R. R. Company" by Emmett Harrell, Elec. Supt., Fairfield Plant, Tennesee Coal, Iron & R. R. Company, Fairfield, Ala.

11:00 A. M.—"Conductors of Heavy Alternating Currents" by D. I. Bohn, Elec. Engr., Aluminum Co. of America, Pittsburgh, Pa., and H. W. Pabst, Engineering Department, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa.

Technical Sessions, Combustion Engineering Division, Cleveland Public Auditorium

General Chairman, W. N. Flanagan, Special Engineer, Carnegie Steel Co., Pittsburgh, Pa. Secretary, T. J. Ess, Comb. Engr., Republic Steel Corp., Massillon, Ohio.

10:00 A. M. "Practical Side of Metallurgical Heating Application" by Harry Dobrin, Consulting Fuel Engineer, Pittsburgh, Pa.

10:45 A. M. "Combustion Control of Open Hearth Furnaces" by Martin J. Conway, Comb. Engr., Lukens Steel Co., Coatesville, Pa.

2:00 P. M. Symposium.
"Electrical vs. Mechanical Devices Used in Combustion Control of Open Hearth Furnaces" by J. F. Shadgen, Smoot Engineering Corp., New York, N. Y.; G. D. Conlee, Republic Flow Meters Co., Chicago, Ill.; P. S. Dickey, Bailey Meter Co., Cleveland, O.; W. H. Shallcross, Shallcross Control Systems Co., Milwaukee, Wis.; R. W. Simpson, American Heat Economy Bureau, Pittsburgh, Pa. M. J. Bradley and B. F. Keene, Leeds and Northrup Co., Philadelphia, Pa.

Thursday, June 18, 1931

Lubrication Engineering Division, Technical Session, Cleveland Public Auditorium

Chairman, C. C. Pecu, Lubrication Engr., Bethlehem Steel Co., Lackawanna, N. Y. Secretary, T. B. Little, A. I. & S. E. E., Pittsburgh, Pa.

9:30 A. M. A Discussion Covering the Questionnaire Sent to the Iron and Steel Industry in Connection with Steel Mill Lubrication Practices by the A. I. & S. E. E. Lubrication Engineering Committee.

10:15 A. M. "Crane Lubrication" by T. J. Flaherty, Elec. Supt., American Rolling Mills Co., Ashland, Ky.

11:00 A. M. "Lubrication of Electrical Apparatus Used in Steel Mills" by J. L. Brown, Mech. Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

2:00 P. M. "Lubrication of Machine Tools" by J. H. Van Campen, Chief Engr., Republic Steel Corp., Plants in Youngstown District, Youngstown, Ohio.

2:30 P. M. "Lubrication of Turbo Generators" by James L. Roberts, Assistant Installation Engineer, Turbine Department, General Electric Co., Schenectady, N. Y.

3:00 P. M. "Testing of Lubricants" by Frank L. Gray, Lubrication Engr., Illinois Steel Co., Gary, Ind.

3:30 P. M. "Testing of Lubricants" by E. S. Glauch, Mech. Engr., Joseph Dixon Crucible Co., Jersey City, N. J.

Thursday Evening, June 18, 1931

Formal Reception, Entertainment and Dance
Cleveland Public Auditorium

General Chairman, F. O. Schnure, President, Association of Iron & Steel Electrical Engineers. Active Committee: J. D. Donovan, C. S. Proudfoot, Walter N. Flanagan, James Farrington, W. E. Miller, N. C. Bye, W. H. Burr, F. W. Cramer, Wray Dudley, J. H. Van Campen, F. D. Egan, J. A. Voss. Honorary Committee: F. W. Jessop, D. H. Martindale, E. G. Bailey, C. L. Collens, W. D. Sayle, C. O. Kennedy, F. R. Fishback, J. F. Herman, William Lintern, E. J. Bartlett, A. J. Thompson, P. C. Clark. Special Feature: Chief Yowlache in Tribal Garb—an Eloquent Interpreter of His Native Indian Songs.

Admission by Card Only

Friday, June 19, 1931

Cleveland Public Auditorium

11:30 A. M.—Inspection Trip to The Goodyear Tire & Rubber Company Power Plants. Inspection of U. S. S. Akron, The World's Largest Airship.

IRON & STEEL EXPOSITION

Cleveland Public Auditorium

June 15-19, 1931

Open Monday, 1:30 P. M.....Closes 10:00 P. M.
Open Tuesday, 1:30 P. M.....Closes 5:30 P. M.
Open Wednesday, 1:30 P. M.....Closes 5:30 P. M.
Open Thursday, 1:30 P. M.....Closes 10:00 P. M.
Open Friday, 9:30 A. M.....Closes 10:00 P. M.

The Successful Installation

By W. S. HALL *

The casual observer of a completed engineering installation is naturally impressed by the appearance of the finished job. The trained engineer is impressed not by what is apparent on the surface of the installation, but by what led up to making the finished installation as it is. He is somewhat familiar with the multitude of decisions which necessarily had to be made, even though he had nothing to do with the particular job he is inspecting. It is the making of these decisions properly and at the same time quickly, which determines the success or failure of any installation.

W. S. HALL

The cost of production is dependent upon two things, namely, fixed charges and operating costs. The success or failure of an installation is not measured by the fact that it does or does not operate successfully, but whether or not it operates successfully at a profit. Unfortunately, in many cases at least, fixed charges are not as apparent to the engineering and operating organizations as actual operating costs. This is liable to create a tendency on the part of those not entirely familiar with the fixed charges to overlook the extent to which these items enter into the success or failure of the installation. The extent to which this is realized by the engineer, largely determines his success or failure. Take the extreme case of the engineer just graduated from one of the technical schools. He leaves college so filled with theory that he does not seem to realize that the entire idea of the installation is to make money. He looks at the installation as an opportunity to apply in many cases, the weird ideas of the theorist regardless of the cost. As his training in the field progresses, he gradually realizes for what purpose the money is being spent. To the extent that he eventually realizes this, is largely the measure of his success.

The time is probably passed when the expression "the best is none too good" can be applied. Both mechanical and electrical design have progressed to such a high state of efficiency that machinery can be purchased which will do what is required of it almost indefinitely with a minimum maintenance expenditure, provided these requirements have been settled at the start of the design. Little trouble is experienced except when the equipment is abused primarily by attempting overproduction. An engineer, therefore, in making his specifications has to make a reasonable allowance to meet these conditions. When production in excess of the original design requirements is attempted, the weakest links in the chain naturally appear first. Under these conditions the engineer should not take too seriously the criticisms which may be forthcoming from those not familiar with the facts involved. To have designed the entire installation to meet these peak demands might have resulted in an investment cost which would have spelled "doom" for the return on the installation, considering the demand for the product over a period of years, for it is over a period of years that the return on the investment has to be figured. Investment charges are always present whether there is any production or not.

Many motor installations have in the past been pronounced lacking in capacity, simply because they would not meet some demand which existed over a comparatively short period. While it is true that operating costs are the lowest with maximum production, the failure to obtain maximum production during these short periods due to some piece of apparatus being too small, does not necessarily mean higher total costs over a period of years.

The installation is successful only when the proper differentiation has been made between the two extremes, namely, operating costs and investment.

* Supt. Engineering and Construction, South Works, Illinois Steel Company, Chicago, Ill.

Utilization of Electricity

Twenty-five Years' Progress in the Steel Industry Through the Development of Rolling Mill Drives

By W. SYKES*

The modern steel mill as we know it today is hardly conceivable without the use of electric power, and I believe it is not too much to say that the wonderful development which has taken place in the past twenty-five years can be ascribed almost wholly to the application of electricity in the mills. It is, of course, almost impossible for the present generation to conceive of a steel mill without electrically driven auxiliaries, but it is not always realized that the development of electrical equipment more than any other one factor has promoted the rapid improvement in the methods, equipment, and product that has taken place in recent years.

It is interesting to review the brief history of mill drives. In the initial installations in this country, which were made about twenty-five years ago, we were mainly concerned with questions of economy. The possibilities of electrical transmission had made it evident that eventually this would become the sole means of distributing power to the different units in a plant. Although there was a feeling amongst those concerned with this development that there were many advantages other than economy, yet to some extent in the early days these advantages were intangible and could only be gradually evaluated as mills of different types were electrified. Twenty years ago we were concerned largely with being able to duplicate engine performance, and had to rely upon the improvements in economy to justify the increased capital expenditure. The question of motor or engine drive did not materially affect the design of the mills then being built. It was demonstrated at an early date that the motor was superior to the engine for the non-reversing mill. The question of reversing mills took some time to demonstrate, but fifteen years ago that problem was definitely settled in favor of electric drive. In the meantime the economy of electric drive had been proven in so many plants that there remained no question at that time as to its merits.

A few years ago a new era began when mills were designed which were only possible with electric drive, and which were not possible with engine drive. With the question of reliability and of economy behind us, and the steadily increasing demands upon the mills for greater production and better quality, it became necessary to devise new layouts. Electricity provided the means to radically depart from the traditional methods. It has caused a veritable revolution in some classes of mills. The modern high speed continuous strip mill is perhaps the best example. Such a mill, of course, would not be possible with any other type of drive, but due to the characteristics obtainable with motors, the new products which such mills produce have changed entirely our ideas of making plate, strip and sheet material. The day of the old fashioned sheet mills is rapidly passing. It involves almost an industrial revolution, affecting the welfare of tens of thousands of people. This can be largely ascribed to the utilization of electricity. These characteristics were the intangibles which we felt were of importance twenty years ago, but which were not appreciated by mill operators. The same characteristics which render strip mills possible are bringing about a somewhat similar revolution in other types of mills. For instance, the straight-away continuous merchant mill has demonstrated that it is a mill of the future for such products. It enables better material to be produced to meet the increasing demands of the consumers for better finish and greater accuracy, and has rendered obsolete the older mill layouts.

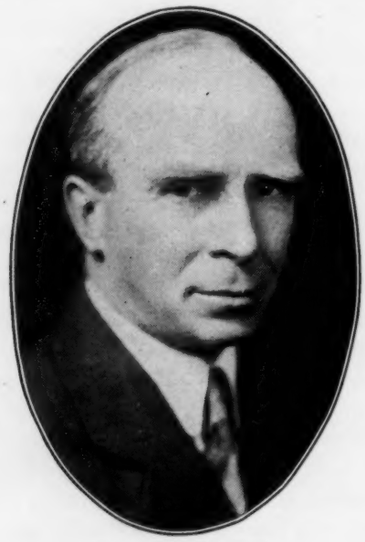
Indirectly such developments are bringing about a new alignment of the steel business in different plants. In addition to the superiority of the products from the highly specialized mills, which electric drive renders possible, the individual units are capable of producing greater and greater tonnages. With this greater capacity there is some sacrifice of flexibility so that it is necessary for the smaller plants to specialize on a few products, or to develop to such an extent that they have a sufficient number of these highly specialized units to cover the whole range of the business. This involves great capital expenditures and leads directly to the merging of small companies into larger units and eventual elimination of the small units which will no longer be able to produce the quality or the quantity necessary to remain competitive. It might well be said that the development of electricity in steel mills is rapidly producing a revolution which affects not only technical methods but also the welfare of thousands of employees, and the financial structure of the industry.

* Assistant to President, Inland Steel Co., Chicago, Ill.

Mutual Helpfulness

By C. L. COLLENS*

No man can live unto himself alone, is an old saying which goes back to the primitive days when organized society as well as organized industry was unknown. But it is equally true in the twentieth century in which we are now living—in fact, the more complicated and extensive both society and industry becomes, the more interdependent we are on each other, and the more groups of individuals or of business units having common interests are drawn together to promote their mutual welfare, or to discuss and solve the similar problems with which each is faced. It is the recognition of this truth which has brought into being such organizations as the Association of Iron and Steel Electrical Engineers and which has fostered in each basic industry a voluntary co-operative organization of the business units, such as the Iron and Steel Institute in the steel industry and the National Electrical Manufacturers Association in the electrical manufacturing industry.



C. L. COLLENS

Our interdependence, however, is even broader than that which finds expression in the organization of an individual group. Time and distance are being conquered by science and inventions, markets are becoming world wide, political barriers have less significance and there can be no disturbance, political, social or financial, in any part of the world or in any industry or group which does not produce its reaction on all or many others in the complicated interwoven social and business structure in which we are now living.

All this is equally true of the relations between the manufacturer and his customers. No manufacturer can afford to live unto himself alone and ignore the interests of the users of his products. Products must be designed to meet the conditions of actual use and to give maximum service. There must be a proper balance between quality and price on the one hand, and life and the cost of maintenance on the other. New products must be designed to meet new requirements or more rigid service conditions. The equipment, methods and manufacturing processes in the steel industry are undergoing continual change and evolution and the electrical products which serve that industry must keep step with this change.

In this evolution and continual change, the Association of Iron and Steel Electrical Engineers affords a forum where the common problems of the electrical engineers in the steel industry can be discussed and where the manufacturers can meet with the steel mill electrical engineers in a spirit of mutual helpfulness. Many examples could be given of the beneficial effects of this joint contact and of the thorough co-operation which it has fostered. The opportunities which your conventions afford to exhibit new products, to gain more intimate knowledge of service conditions and to discuss with men who are experts in their field, design and engineering problems, have been of inestimable value to all electrical manufacturers.

The close association between the steel mill electrical engineers and the electrical manufacturers is not limited to the benefits which result from co-operation on engineering and technical subjects. Business relations are becoming less and less a matter of cold-blooded negotiation between two opposing forces, each intent on gaining some real or supposed advantage over the other. Business relations to be satisfactory must be mutually beneficial and must be founded on mutual confidence and respect. Other things being equal, we like to do business with our friends and the conventions of the Association of Iron and Steel Electrical Engineers afford an opportunity for developing the friendships and the mutual confidence and respect on which all satisfactory business relations are based.

May your Cleveland convention prove highly successful and still further promote the spirit of helpful co-operation which now exists between the steel mill electrical engineers and the electrical manufacturers.

* President, Reliance Electric and Engineering Company, Cleveland, Ohio.

Welding and Its Possibilities

By W. SPRARAGEN*

"A Twenty-Story Building Silently Erected by Welding," "Welding Enables Use of Heavier Guns on German Ships," "Thousand-Mile Oil Line to be Welded" and " Welding of Four-Inch Pressure Vessels Now Possible," are now familiar newspaper and technical press headlines. As a matter of fact, these are only a few of the outstanding recent accomplishments in the welding field.

Behind these headlines, however, are stories of cooperative effort of an industry in solving their common problems and the pioneering effort of individuals and companies. Some fifteen years ago welding was employed principally to repair broken

W. SPRARAGEN

parts of machinery and other metal parts; some times with indifferent success. Since the World War, however, the various welding processes came into their own rapidly because speed of production in every metal-using and metal-fabricating industry soon became a vital factor.

At first welding was limited to use on small or less important parts, but as favorable experience soon showed the desirability, its field of application was gradually extended to heavier and more important construction and repair work. Many practical demonstrations of the utility of welding focused attention on its marked economic advantages with the result that now all welding processes are widely used in all branches of manufacturing. Welding is employed for an almost limitless number of applications from the manufacture of such small articles as watch-stems to the largest metal-fabricated structures —ships, locomotives, trunk oil and gas pipe lines, gas tanks and the largest turbine electric generators.

Development of welding applications was so rapid that the new art did not always show to the best advantage. The apparent simplicity of gas and electric welding led to its use by untrained workmen and in applications where the design of the joint between the parts to be joined or the nature of the material were not entirely adaptable to welding by the particular method used. Consequently some unsatisfactory work was done which resulted in delaying the day when engineers and the public at large were willing to accept welding with full confidence.

This condition was recognized by a number of far-seeing men interested in the conservative development of welding, and as a result, the American Welding Society was formed in 1919 for the broad purpose of putting the welding art on a sound, scientific and engineering basis. It was appreciated that only with such a foundation could welding ever be recognized as a thoroughly reliable process and be accepted for general employment in industry.

The American Welding Society is an organization of individuals and also companies and corporations interested in welding by any process—either as manufacturers of welding equipment and supplies interested in the commercial acceptance of the art, or as users concerned with its efficient application.

Advance in Structural Welding.

The gradual development of an industry or a branch thereof always forms an interesting story, although it is difficult at times to piece this story together.

As a matter of fact, the welding of minor structures was successfully carried out even fifteen years ago. These structures included a few minor buildings, some small ships and a few large tanks. Successful experience in these applications led to greater confidence and serious investigations of the various problems involved. Technical papers began to appear. Tests were conducted by the research department of the American Welding Society, known as the American Bureau of Welding, by large and small companies, in governmental laboratories, universities and by individuals. Larger buildings were then fabricated. Problems of design, management, preparation of material, technique of fabrication, training of welders, inspection and supervision, were successfully solved.

Parallel investigations proceeded on metallurgical problems, stress distribution and other fundamental matters. Concentrated effort was put forth by the industry and the American Welding Society in the presentation of papers before engineers and responsible bodies on every phase of the subject.

A comprehensive series of investigations were outlined by a Structural Steel Welding Committee of the American Bureau of Welding, sponsored by the American Institute of Steel Construction, manufacturing companies and leading fabricating shops. Test specimens were made up under careful specifications in some forty leading fabricating shops in order to yield fundamental design data on various types of joints and thicknesses of material commonly met in practice. A building code was promulgated by the Society which has been adopted whole or in substance by more than a hundred municipalities. As a consequence, during the last few years a large

* Technical Secretary and Editor, American Welding Society, New York, N. Y.

number of important structures of all types have been fabricated in part or in whole by welding.

Pressure Vessels

One of the greatest advantages of welding lies in the fact that a joint can be made oil, gas and water tight up to its breaking point, whereas, riveted structures leak at pressures much less than 50% of their ultimate strength. Moreover, the strength of the original plate may be equalled by a welded joint as there is no loss of material due to punching of holes. This enables the use of lighter tanks for given pressures except where such thickness is determined by limits of corrosive action.

With such advantages it would appear that the use of welding in pressure vessels would have been accepted from the start. However, the situation is not quite so simple. Regulatory and insurance bodies primarily concerned with safety are loath to permit the use of any process unless its safety can be assured in advance all of the time. The extension of the application of welding in this field has been therefore, a slow and tedious process. On the one hand, conservative engineers had to be convinced that welding properly applied was safe and, on the other hand, suitable technique and procedure had to be developed which would definitely assure the success of the finished product.

We find, therefore, that at the outset fusion welding was entirely prohibited in the construction of pressure vessels. Through a gradual process of education and experience, welding began to be used on some of these vessels. A series of investigations conducted by the American Bureau of Welding at the U. S. Bureau of Standards resulted in fundamental knowledge which enabled the Boiler Code Committee of the American Society of Mechanical Engineers to recognize welding to a very limited extent. Additional tests by individuals, companies and service experience gradually led to the promulgation of specifications which covered such items as material, design, technique of welding, qualification of welders, inspection and test data. These specifications in turn brought about a gradual degree of confidence so that more liberalized rules were made possible.

In the meantime, many industries have found it necessary to go to pressures and temperatures undreamed of ten or fifteen years ago. This, in turn, has required material 2″, 3″ and 4″ in thicknesses. The limits of fabrication by riveting were soon reached and the use of welding was practically made mandatory. Research work kept pace with this gradual development and new methods and technique were developed which yield welds of vastly superior physical characteristics than were available a few years ago. These welds not only have tensile strength equal or superior to that of the parent metal, but also rival it in ductility, impact and fatigue resistance. Here again, the story of the gradual development of the use of welding would occupy a good size volume and would include among its pages the romantic story of the pioneering effort of individuals, companies and laboratories, as well as, an untiring effort on the part of regulatory bodies, such as, the American Society of Mechanical Engineers' Boiler Code, to keep abreast of the latest developments of a rapidly growing industry in order that they might temper the necessity of conservatism and safety in their actions with progress so as not to place unnecessary and unjust restrictions against a serviceable tool to industry.

Other Applications

I have only mentioned very briefly two branches of welding to indicate the process of development. A similar story could be told in the application of welding to piping and pipe lines where literally thousands of miles of pipe ranging up to 5 feet in diameter carry oil, gas and water with practically no pipe line maintenance cost. Again, the applications of welding to aircraft structures, to railroad and plant repair and maintenance, to tank and ship construction, are more or less, familiar to all of us. A somewhat newer application is the gradual but steadily increasing use of welding in the manufacture of machinery of all sorts. Welded structural shapes accurately cut by the torch are replacing use of castings and increasing the use of steel. As indicated in the opening paragraph some of our largest turbine electric generators are now fabricated entirely by welding.

Cooperation and Team Work

Although the author has stressed the importance of team work and cooperation in this development, the story would be incomplete without giving due credit to the research investigator at the university. He is constantly extending the frontiers of knowledge. Although his investigations at times may appear theoretical and somewhat remote from practical applications, nevertheless, in its gradual development, the welding industry seizes and makes use of the knowledge thus made available. For example, the investigations on strength of welds at high temperatures have given confidence to the use of welding for pipe lines carrying high pressure superheated steam. Study of fatigue properties of welds has enabled the designer to design his structures with assurance of safety. The theoretical investigations of stress distribution have enabled the structural and bridge engineers to better locate and proportion their welds so that they will give a maximum of service. X-ray and other non-destructive tests for welds have given industry a tool to examine such structures as pressure vessels and boiler drums before they are put in service thus eliminating any element of risk. Studies of heat treatment and stress relief have, also, served similar useful purposes.

Cleveland Welcomes The A. I. & S. E. E.

By P. C. CLARK*

The Association of Iron and Steel Electrical Engineers is holding its Twenty-Seventh Annual Convention this month, having selected the excellent convention city of Cleveland for such purpose.

It is therefore proper that Industrial Cleveland should dust off the "Welcome" sign and make it look as if it means just what it says.

P. C. CLARK

This Association of Iron and Steel Men deserves a real welcome. Collectively and individually these men have earned the right to be considered as the foremost exemplification of progress in Industry.

As a matter of fact, this Association has outgrown its name. Starting with a small group of far-seeing electrical men this organization has developed steadily and in a healthy manner until it is now proud of a membership which represents not only the Electrical but many other equally important phases of endeavor in Iron and Steel and allied industries.

Yes, indeed! This A. I. & S. E. E. has set up a standard of progress difficult to eclipse and excellent to follow. Speaking of standards and as illustrating the "Never Say Stop" spirit, this Fraternity is right now sponsoring an idea which has as its ultimate aim, a standardization program involving control equipment in general. This should certainly be welcome news to the manufacturers of this line. There is plenty of room for recommended standards in this work. Connection Diagrams, Symbols, Location of Terminals and Terminal Boards, Relative Location of Contactors and Relays and many other phases of the subject could be considered with advantage.

The Association is to be congratulated on its activity in this direction, and when the work has progressed to a point where it is feasible to do so, I believe the Manufacturers will welcome an invitation to give the subject serious consideration. This idea should be carried to a conclusion so that the present unnecessary differences in essentials may be harmoniously welded into definite standard form for the good of the Industry as a whole.

May I respectfully suggest the National Electrical Manufacturers Association (NEMA) as the medium through which the attention of all the Control Manufacturers may be most efficiently reached.

*President, The Clark Controller Company, Cleveland, Ohio.

A Manufacturer's Opinion of the Value of Engineering Societies, Their Periodicals and Expositions

By WILLIAM LINTERN*

From the standpoint of a pioneer in electrical work dating from the early days of electric traction, Engineering Societies, their Periodicals and Expositions, have been foremost in progress, affording the technical man a means of keeping in step with progress.

In the Eighties of the past century, when lighting, power and electric traction began to appear, practically all working knowledge was obtained from publications. Most of the articles in these publications lacked the practical viewpoint, and this inspired the formation of organizations for the exchange of ideas. This was done by both engineers and non-technical men, and proved to be of great assistance to all concerned.

Consider the position of the early worker in the electrical industry who more than likely had acquired

* President, The Nichols-Lintern Co., Cleveland, Ohio.

an education in the common schools of more or less degree. There was little stimulus to better knowledge unless he had a natural inquiring mind. Fortunately many had that sort of mind and delved into all the printed matter available. Knowledge gained in this way found a necessity for expression by conference with others. So insistent was this demand for exchange of ideas that various small organizations were formed, with meetings at which the problems of local conditions were discussed, and quickly extended to conditions that were not under direct observation. Electrical Unions formed special classes for this purpose.

WILLIAM LINTERN

These early efforts were for the worker a continual source of knowledge that resulted in development on his part, the result being that the practical worker has taken a large part in the development of the electrical industry as of today. To look back to the crude designs of brush holders, insulation methods, gearing lubrication and a multitude of other items, a great amount of credit is to be given the worker for refinements and further steps to betterment that he stimulated. The closer he followed current thought through periodicals the greater his efforts and achievements, in many cases originating ideas that were finally expressed in the foundation of a business, some of which are now prominent in electrical affairs throughout the world.

The technical men soon formed engineering societies in order that they might become familiar and keep abreast with the rapid developments. This enabled them to secure information and data not available from any other sources.

Developments in the electrical field are even more rapid today and they will continue on, at a swift pace. Engineering societies, with their invaluable meetings, conventions and periodicals offer an opportunity that is an absolute necessity to a man in this field of activity and he cannot afford to disregard it.

During the present depression some of the engineering societies have been conducting employment agencies for engineers who have lost their positions. One of these organizations reports the very interesting fact that 80 per cent of the men applying for positions are not members of any active engineering society. The men active in engineering societies have an opportunity to broaden their scope of activity to an extent that they are able to continually make savings and developments, so that they are of even greater value to their organizations now than when prosperity reigns.

To the manufacturer, the Society Periodical is exceedingly helpful. He can of course through advertising in it bring his products directly before the men who actually need them. He also has an opportunity of presenting his ideas, and at times his products before a meeting of operating engineers on a purely scientific basis. It will be discussed from every angle by these men without "fear or favor" with the result that he obtains very valuable information.

Representation at all meetings, conventions and expositions is of unlimited value, as acquaintances and contacts formed, and information secured, often lead to direct sales that otherwise would be "lost" or left undeveloped.

The expositions and conventions give the operating member and the manufacturer an opportunity of investigating thoroughly all new developments in his field, to see equipment in operation under various conditions and to discuss papers and items of interest with men from various parts of the country and at times from all parts of the world. The expositions give the manufacturer the advantage of placing his equipment immediately before his prospective customers.

Did We Lose In 1930?

By F. W. JESSOP*

The majority of companies and individuals made less profit or showed financial loss for the year 1930 as they did in 1908, 1914 and in 1921, but if one studies the conditions carefully, these were years of progress and in the long run, gain for aggressive individuals, as well as companies.

A few men are so constructively ambitious that they are constantly analyzing their present situation and actively scheming and working to improve it. Very often this is a selfish mistake and results only in a rolling stone life with no real lasting benefit.

The older you grow the more you will realize that really good, strong capable men are hard to find in any walk of life, be it production, selling, managing, finance, engineering or professional. If, therefore, you are able to maintain good health, are fairly well trained in your chosen field and are located with a good company, big or little, you have only to give good, intelligent service to insure your rising, though some naturally climb faster than others.

F. W. JESSOP

Personally I started my business life with no influence, no capital and no genius and did not expect that I could ever rise beyond a reasonable living wage but I soon found that most men try to get by with the least effort and that genius was not required, but only hard, earnest, intelligent effort.

There are, of course, many different situations that must be considered. In some cases the company or its line of product is at a stand-still and there seems little chance for anyone connected with it to progress. In other cases a man may be obstructed by a jealous superior or by family favoritism. Occasionally and enthusiastic superior will advance a young man faster than he can grow and sooner or later he drops with a dull thud, sometimes as a result of the drop of the unwise superior.

In general it is wise to take stock of your situation and that of your company from time to time, but do not expect too rapid advancement. Look up the record of successful men and note that the steps by which their advancement was recorded show intervals of years, not months.

Men who complained in 1929 of too much work which interfered with golf or speculative activities have discovered that the work they are permitted to do is actually interesting and the regular pay a Godsend.

In our company as in most others, we were working overtime in 1929 to produce and ship orders; our customers were less critical than they might have been because they needed our product to complete their own; our tool department was struggling to keep the shop supplied with jigs, tools and fixtures.

We had a research department but no one had a great deal of time to give to its work and our existing products were apparently giving such universal satisfaction that research seemed a bit superfluous. We considered improvements but it is difficult to break into heavy production to make changes and they call for heavy and apparently unnecessary expenditures.

Possibly if Alexander, Caeser and Napoleon had not conquered others so easily, they would have had more time to devote their undoubted genius to the improvement of their own people and earned a more wholesome fame.

In 1930 we had periods of hesitation in orders and production and our customers were offered competing product with claimed improvements at attractive prices which kept us hustling to meet. We realized that competition as to price and quality would be more aggressive than ever before and we had time to study each item of material and labor and we went at them to improve quality and accuracy and performance and in some cases we did all three at reduced cost.

The progressive steel companies, big and little, have been hard at the same task with the result that we have better pipe, better sheet, better beams and new types of steel to meet special requirements. Some of these, like stainless steel, have revolutionized industry and greatly added to the sum total of steel required.

Electric welding has been improved so butt joints in steel .03" thick can be welded perfectly and with no fear of burning. Rail joint defects can be built up with metal welded on as hard and tough and more durable than the original rail. Large buildings, ships, tanks, bridges and other important structures are now welded.

In general 1930 has not been a year of big production or big current profits but it has been a year of intensive study, important improvements in processes and new products that will help to make the coming decade more prosperous than the last one

* President, Ohio Electric Manufacturing Company, Cleveland, Ohio.

for those who manage to keep up with the procession and that means individuals as well as corporations.

There are more people now than ever before who wish to buy our products in order to increase their own sales or improve their processes and our task is to find the ones who have the courage and ability to go ahead.

Are We Becoming Less Efficient?

By F. R. FISHBACK *

The past ten years have been largely characterized by mergers and mass production.

The primary object of a merger is to reduce costs and the primary object of mass production is to reduce costs.

As a result of this thinking the tendency has been to reduce prices and to sell at the lowest price possible. In some cases, in order to keep up production, goods have been sold at cost or less. The major thought has been that of low cost. Research departments have devoted their energies mainly to the question of cutting costs.

All this has caused the buyer to think more and more of first cost and to put into the background the question of upkeep cost. We get just what we pay for. If we buy machinery at the lowest bid price, it does not mean that we are buying it in the most efficient manner. It is possible and probable that it is the most inefficient to maintain. We are saving on first costs but we are adding to maintenance.

Ordinarily, upkeep cost is considered as the cost of keeping a machine running. There is another and more important factor, and that is, the cost of shutdown. In computing the efficiency of any machine, three factors should be primarily considered: Cost of Shutdowns, Cost of Maintenance and First Cost. Are we giving too much thought to the one factor of First Cost?

The operating engineer, to be true to his profession and to his employer, should consider these things and consider them seriously:

First: Is this machine I want to buy the most efficient for the particular job I have in mind? Will it make that part of my plant efficient?

Second: Will it have the minimum upkeep cost?

Third: Will it reduce shutdowns in our plant?

Fourth: Is the price right after considering everything else?

After the operating engineer has completed his studies and made up his mind to be efficient, he should stick to his guns.

Are operating engineers doing this in spite of all pressure brought to buy the cheapest?

The buyer, however, is not entirely to blame. The manufacturer through his agent, the salesman, has felt the pressure and has resorted to tactics that reduce efficiency. The salesman in order to still further reduce his selling price, will increase the rating of a machine and "take a chance." Or he will omit certain characteristics of his machine. In many cases this action will reduce the efficiency of his machine for that particular job. Back of this is the mass production idea. Each salesman must get more orders. The question of a salesman building up good will and giving service is subordinated to the idea of more orders. More orders means more production and more production means lower costs and lower costs means lower prices and so the cycle goes.

Is the manufacturer selling more machinery for the dollar or is he selling more efficiency for the dollar?

Is the salesman making an intelligent study of the engineer's problem and proposing the best machine possible for that particular job? And then, is he insisting on selling that machine and that particular, efficient machine?

Then take the third part of the triangle, the purchasing agent. His duty is to buy at the lowest price. But the efficient purchasing agent says the lowest price is the lowest one consistent with quality and the work to be performed. It may not be the lowest price measured in dollars. Mass production tells him to buy cheaper and cheaper.

Is mass production lowering the efficiency of purchasing?

A truly efficient organization is one that has at its head a management that says: "We have an engineering staff that is of the best and we respect their findings and their decisions. We have a sales force that can sell and they are proud of their goods and of their personal ability to sell. They are not asking for help. We have a purchasing department that gets the most for our money without sacrificing efficiency in production or quality of our product."

The perfect triangle is that in which no side predominates. The engineer on one side carefully formulates his decisions with the help on the second side of a salesman who is honest with him and a salesman that knows what he is doing and can be trusted. On the third side, we have the purchasing agent who consults freely with both the engineer and the salesman and buys the most in value to his company.

This means efficiency for the Company.

Is there such a triangle in our organizations? Or is this triangle disappearing? If it is not disappearing, isn't this triangle at the present time lopsided.

* President, The Electric Controller & Mfg. Co., Cleveland, Ohio.

INSPECTION TRIP

Power Plants and Machinery

GOODYEAR TIRE & RUBBER CO.

AKRON, OHIO

FRIDAY, JUNE 19th, 1931

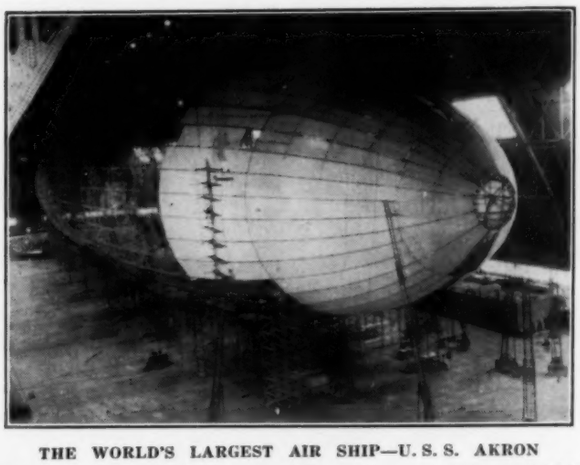
FEATURES

2 Power Houses, having a combined capacity of 55,000 K.V.A.
Boiler Rooms, 28,800 boiler H.P.
Fired by Pulverized Coal.
Electrical Transmission 2,300 Volts.
Total Connected Motors load 84,000 H.P.
THE WORLD'S LARGEST AIR SHIP—U. S. S. AKRON.
THE WORLD'S LARGEST AIR SHIP DOCK.

Trip MUST BE made via busses.

Busses leave 11:30 A. M.—Cleveland Auditorium

Full particulars at Registration Desk, Cleveland Auditorium, 9:30 A. M. to 11:30 A. M., Monday, Tuesday, Wednesday, Thursday. Reservations for trip close THURSDAY, JUNE 18, 1931.



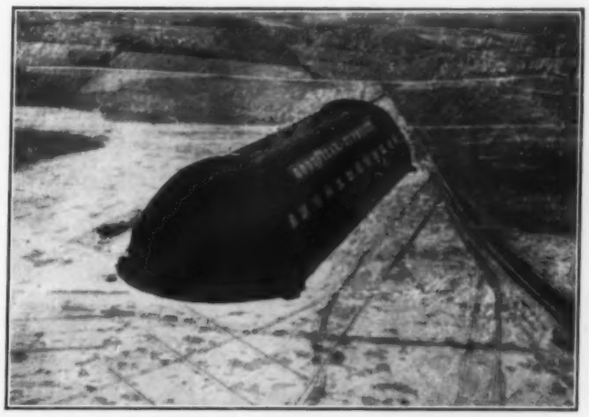
THE WORLD'S LARGEST AIR SHIP—U. S. S. AKRON

Some of the interesting engineering features of THE WORLD'S LARGEST AIR SHIP'S are as follows:

Principal Characteristics of the Los Angeles, the Graf-Zeppelin and the U. S. S. Akron

Name	Los Angeles	Graf-Zeppelin	U. S. S. Akron
Nominal Gas Volume, Cu. Ft.	2,470,000	3,700,000	6,500,000
Length Overall, Ft.	658.3	776	785
Maximum Diameter, Ft.	90.7	100	132.9
Height Overall, Ft.	104.4	113	146.5
Gross Lift, Lbs.	153,000	258,000	403,000
Useful Lift, Lbs.	60,000		182,000
Number of Engines	5	5	8
Total Horsepower	2,000	2,750	4,480
Maximum Speed, Miles Per Hour	73.1	80	83.8
Range Without Refuelling at 50 Knots Cruising Speed, Land Miles	4,000	6,125	10,580

A special feature in connection with the Inspection Trip will be Lieutenant-Commander C. E. Rosendahl of the U. S. Navy, who has prepared a special lecture, describing many interesting engineering features of THE WORLD'S LARGEST AIR SHIP, THE AKRON, now being built by The Goodyear Zeppelin Corporation at Akron, Ohio.



THE WORLD'S LARGEST AIR SHIP DOCK

Facts About the World's Largest Air Ship Factory and Dock

The length is 1,175 feet between center lines of door tracks; its width is 325 feet center to center and its height 197½ feet from center of lower to center of top pins. The height from the floor of the platform at the top is 211 feet.

Hangars of similar design although smaller, have been built at Dresden and Liegnitz in Germany.

Comparison

It is the largest structure in the world without interior supports.

Ten football games could be played simultaneously under its roof.

Six miles of standard railroad tracks could be laid on the floor area.

The great Woolworth Building could be laid inside and the Washington Monument "thrown in" for good measure.

The building would house the airplane carriers "Saratoga" and "Lexington" together with the Washington Monument and the Statue of Liberty.

Its height is equal to a 22-story building.

The dock covers eight and one-half acres. Walk the length of it four times and you've traversed almost a mile.

The sheeting covering the structure, if laid out flat, would equal 18 acres.

There's room inside for 49 airships the size of the "Defender" largest of the Goodyear fleet, or 60 average-sized barns found on the farm.

Previously the largest hangars in the United States were those at Lakehurst, N. J., and Belleville, Ill. The former has a length of 803 feet, a span of 264 feet, and a height of 172 feet to the upper pin. It is intended to house two large ships. The latter has a length of 810 feet, a span of 150 feet and a height of 150 feet.

These have vertical doors that open horizontally, from the center outward.

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J. J. BOOTH,
General Convention Chairman.

J. D. DONOVAN,
Chairman, A. I. & S. E. E. Steam Generation and Utilization Section.

S. S. WALES,
Chairman, A. I. & S. E. E. Welding Committee.

Prominent Steel Mill Engineers, who will be active in the various Technical Sessions of the A. I. & S. E. E. Convention and Iron and Steel Exposition at Cleveland, Ohio, June 15th-19th, 1931.

W. N. FLANAGAN,
General Chairman, Combustion Engineering Session, Wednesday, June 17th.

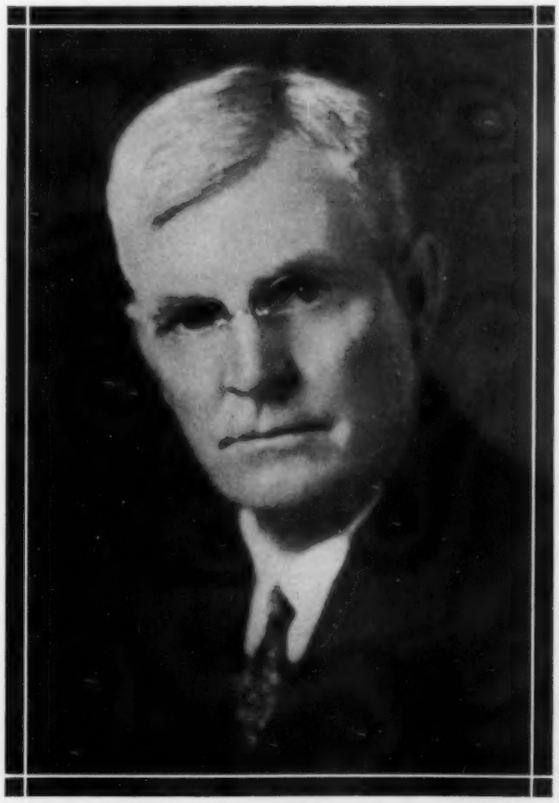
J. A. VOSS,
Chairman, Safety Engineering Session, Monday, June 15th.

C. C. PECU,
General Chairman, Lubrication Engineering Session, Thursday, June 18th.

M. J. CONWAY,
Chairman, A. I. & S. E. E. Instrument and Control Section of Combustion Engineering Division.

A. L. REICHERT,
Chairman, Industrial Plant Visiting Committee.

R. S. SHOEMAKER,
Chairman, A. I. & S. E. E. Development in Rolling Mill Practices Committee.



C. S. PROUDFOOT,
Chairman, A. I. & S. E. E. Electric Heat Committee.

J. H. VAN CAMPEN,
Chairman, Invitation and Ticket Committee for A. I. & S. E. E. Convention and Iron and Steel Exposition.

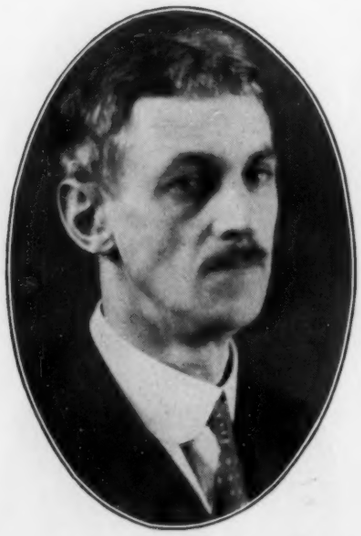
T. J. FLAHERTY,
Chairman, A. I. & S. E. E. Air Conditioning Committee.

D. I. BOHN,
Author.

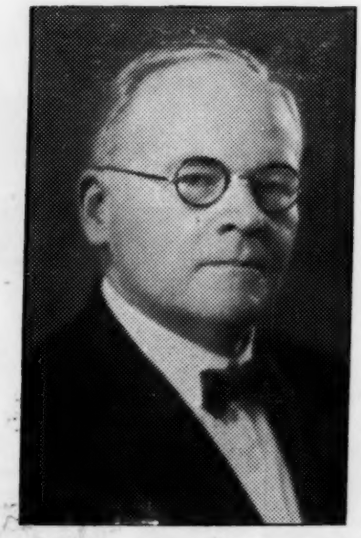
C. R. SABIN,
Secretary, Cleveland Engineering Society.

R. H. WRIGHT,
Author.

Representative engineers from every steel center in the United States and Canada will present papers or discussions at the Twenty-seventh Annual Convention and Iron and Steel Exposition of the A. I. & S. E. E. at Cleveland, Ohio.



H. E. STOKES,
Author.



R. C. McBRIDE,
Author.

W. W. SPANAGEL,
Secretary, Cleveland Section, A. I. & S. E. E.

Electrical Developments Committee Report—1930-1931

By W. H. BURR*

Although many industries experienced unfavorable conditions during the year 1930, due to the world wide economic crisis, the steel industry was especially active in electrical development.

W. H. BURR

Main drive motors which a few years ago were thought to be nearing perfection, have been materially improved in design and automatic control has been so perfected that modern mills appear to be operated by some magic power in the hands of a master magician. Electrical heating has advanced another step and is now generally recognized as the ideal method of heating modern alloys and electric welding is revolutionizing the method of producing many steel products.

Such competition as exists today makes it necessary to electrify older plants and to be constantly on the lookout for new methods and new processes which will effect greater economics in production costs in plants already electrified.

When it is seen that during the year 1930, 109 Main Roll drives of 300 HP or over were installed as compared with a total of 201 during the previous year, you can readily visualize the condition of business in the steel industry. The total HP in Main Roll drives installed during the year was 158,440 as compared with a total of 313,000 during the previous year.

From the fact that of this total of 109 motors installed, 70 were DC motors, it is evident that DC Main Drive motors are considered more suitable for most applications than AC motors. DC adjustable speed sets were used almost exclusively and 75% of all the drives installed were geared units.

In the distribution of steel products it is interesting to note that 20% of all the steel production went into bars, 15% was used for sheets, which is exactly the same percentage as 1929, and pipes, shapes, and plates each represented about 11% of total production.

The tonnage of steel products used in the electrical industry is increasing each year. Of the 505,000 tons manufactured for this industry during the year, almost one-half was black plate and sheets. This total is, however, only a small percentage of the 40,000,000 tons of steel produced during the past year.

Main Roll Drive Charts

As has been the custom for several years, charts showing the progress in electrification of Main Roll drives in the steel industry have been prepared. This year, however, they have been worked up in a somewhat different form.

The chart covering the total number of Main Roll drives installed indicates clearly the sharp decline in the purchase of steel mill equipment during the year. It also shows that notwithstanding the depression, there were more drives sold in 1930 than in 1927.

The chart showing total HP installed brings out clearly the fact that the years 1925-6-8-9 each exceeded 1930 in total HP of motors installed. We see from this also that over 2.5 million HP has been installed on Main drive motors since 1905.

On Structural mill drives, the curve drops to a point very close to where we started 25 years ago.

A total of 32,500 HP was installed on Merchant mills during 1930 which was the greatest total HP installed on any type of mill last year.

Plate mills after a period of very little activity broke all records for total HP installed in one year. This, however, represented only one installation, that at the Illinois Steel Co., South Chicago.

No new Sheet Bar or Skelp mill drives were installed during the entire year. Not since 1921 has this condition existed.

It is an unusual condition, but from the curves it is evident that the total HP installed on Main Roll drives on Plate mills exceeded the total HP installed on all Blooming mill drives last year.

In 1929, no Rod mill drives were installed which makes it easy to show improvement in this field.

Bar and Billet mills after a record year in 1929 dropped back to a total of 20,950 HP in 1930. The total HP installed on Main Roll drives on Bar and Billet mills now exceeds that on any other type mill.

During 1929, 70,000 HP in motors was installed on Strip mills alone. This represents the greatest total HP ever installed on any single type drive in one year. From this high point, the total in 1930 decreased to 25,000 HP.

*Chairman, A. I. & S. E. E. Electrical Developments Committee, and Electrical Supt., Lukens Steel Co., Coatesville, Pa.

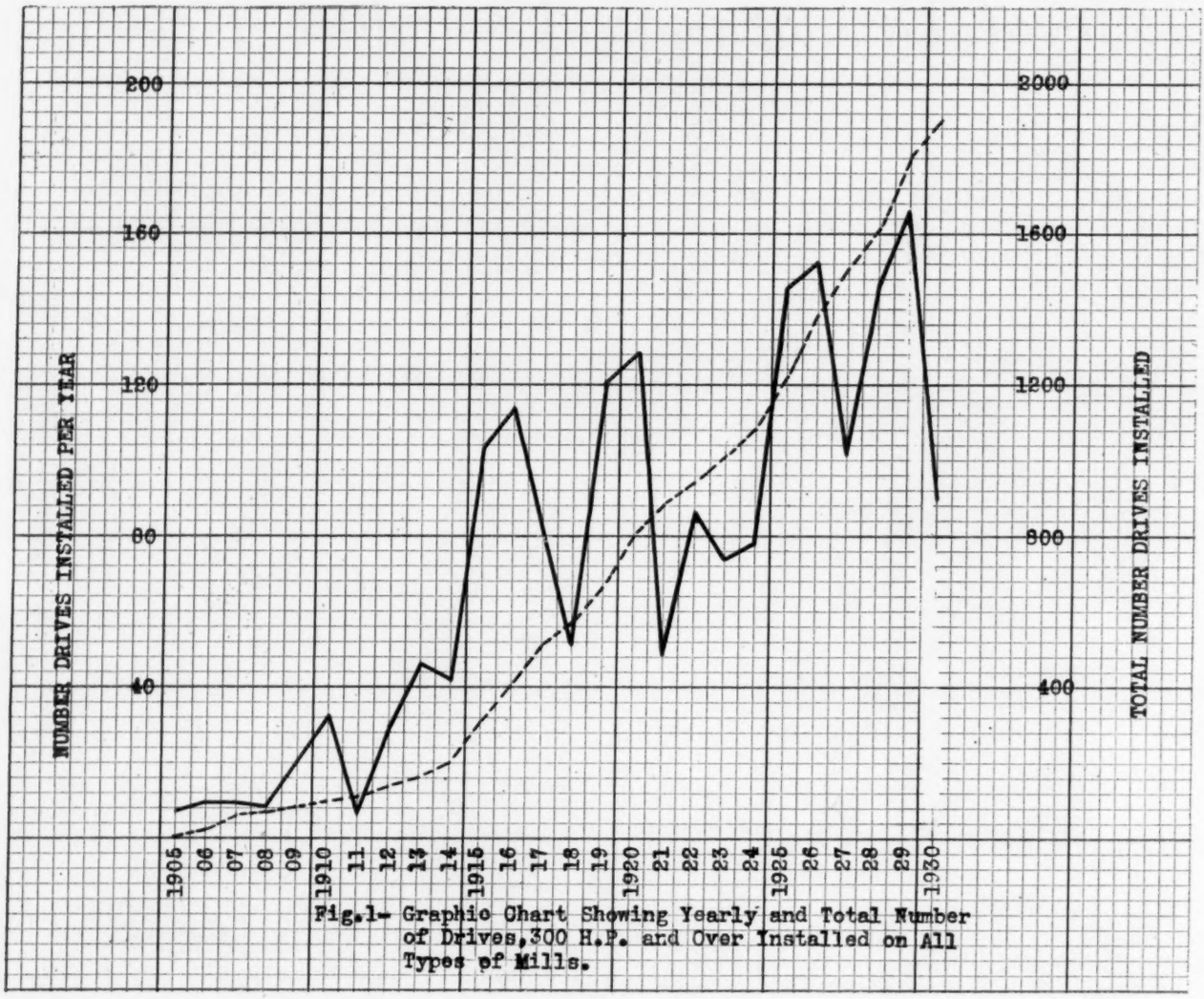


Fig. 1- Graphic Chart Showing Yearly and Total Number of Drives, 300 H.P. and Over Installed on All Types of Mills.

Turbines

The largest Industrial Turbine ever built is being installed at the River Rouge Plant of the Ford Motor Co. The boiler units consist of two double sets of Ladd boilers, each having a water heating surface of 50,000 square feet with a steaming capacity of 700,000# per hour, the greatest of any high pressure boiler yet built. This installation provides for a pressure of 1400# per square inch and the boiler installation has a guaranteed efficiency of 86.5%.

It is expected that when this installation is completed, one KWH will be produced from 13,000-14,000 BTU. The steam developed in these boilers will drive the new steeple type compound turbine generator rated 110,000 KW at 90% P.F.

For several years the steam pressure used on turbines has been increasing so that we are becoming accustomed to talking of high pressures in connection with turbines, but it now develops that vertical steam engines are being built which will be operated on 1800# steam pressure. Although this would seem to be a very difficult engineering problem, in view of past accomplishments this new development is worthy of careful consideration.

Mercury Vapor Turbines are now being offered for industrial power purposes. A turbine of this type has been in continuous commercial operation over a period of some nine months and has shown remarkable economy. For a period of several days it gave a net economy of 9800 BTU per KWH and for a period of some nine months an economy of 10,180 BTU per KWH. The ease in operation and lack of vibration is very apparent. Experience during the year would indicate that the maintenance cost will be less than with standard steam equipment. Designs and plans are under way for the installation of equipment having double the capacity of present equipment.

Transformers

The growth in the use of the non-resonating type of construction for high-voltage transformers, by means of which internal voltage oscillations are eliminated through the use of electrostatic shields, is indicated by the fact that during the year there were constructed by one manufacturer a total of 66 units of this type aggregating more than 1,250,000 kv-a. in capacity. Of this total, 38 units aggregating about 765,000 kv-a. were for service on 220-230 kv. systems.

An air-blast transformer of record current rating was constructed for supplying resistance welding circuits. It has a normal continuous rating of 150,000 amps. at 30 volts, 60 cycles, and a reactance of about 2½ per cent. The air circulation is axial along the middle leg of the core and then radial between the coils.

It is interesting to note that there has been built recently a self cooled transformer, having a rated capacity of 40,000 kv-a.

Main Roll Drives

There was a time when Rolling mills were designed and the main drives made to conform to the other requirements of the mills. This condition no longer exists, for modern electrically driven mills are so planned that the most efficient drive known can be utilized. In fact, the designs of the mills themselves have been revolutionized in order to take advantage of the latest developments in electrical industry. Never before has this fact been so apparent as during the past year.

At the present time, there is under construction a 44" Universal Slabbing mill drive having a continuous capacity of 12,500 HP and a maximum emergency capacity of 35,000 HP. The upper and lower rolls on this mill are to be individually driven by two 5000 HP, 40-80 RPM motors, constituting a twin motor drive of 10,000 HP having a maximum torque capacity of 4,000,000 pound feet. This motor is a duplicate of the twin motor drive on the 54" Blooming mill already in service. The vertical edging rolls on the slabbing mill are to be driven by a 2500 HP, 79-225 RPM motor. The power for the main roll drives will be furnished by 10,500 KW, 700 volt flywheel motor generator set consisting of 180,000# flywheel, 6500 HP motor, 370 RPM, and three 3500 KW, DC, 700 volt generators in parallel. This drive is of such unusual interest that very complete information regarding it will no doubt be given before the Association.

Another development which is attracting considerable attention is being installed on a 10" Bar mill. There are two vertical stands each driven by an 800 HP vertical motor, one designed to operate from 195-495 RPM, the other 285-705 RPM. The motors are mounted on structural stands over the vertical rolls and pinions. This is believed to be the first application of vertical main roll drive motors and represents a distinct improvement over previous methods of drive.

At the present time a 10" Alloy Bar mill, driven

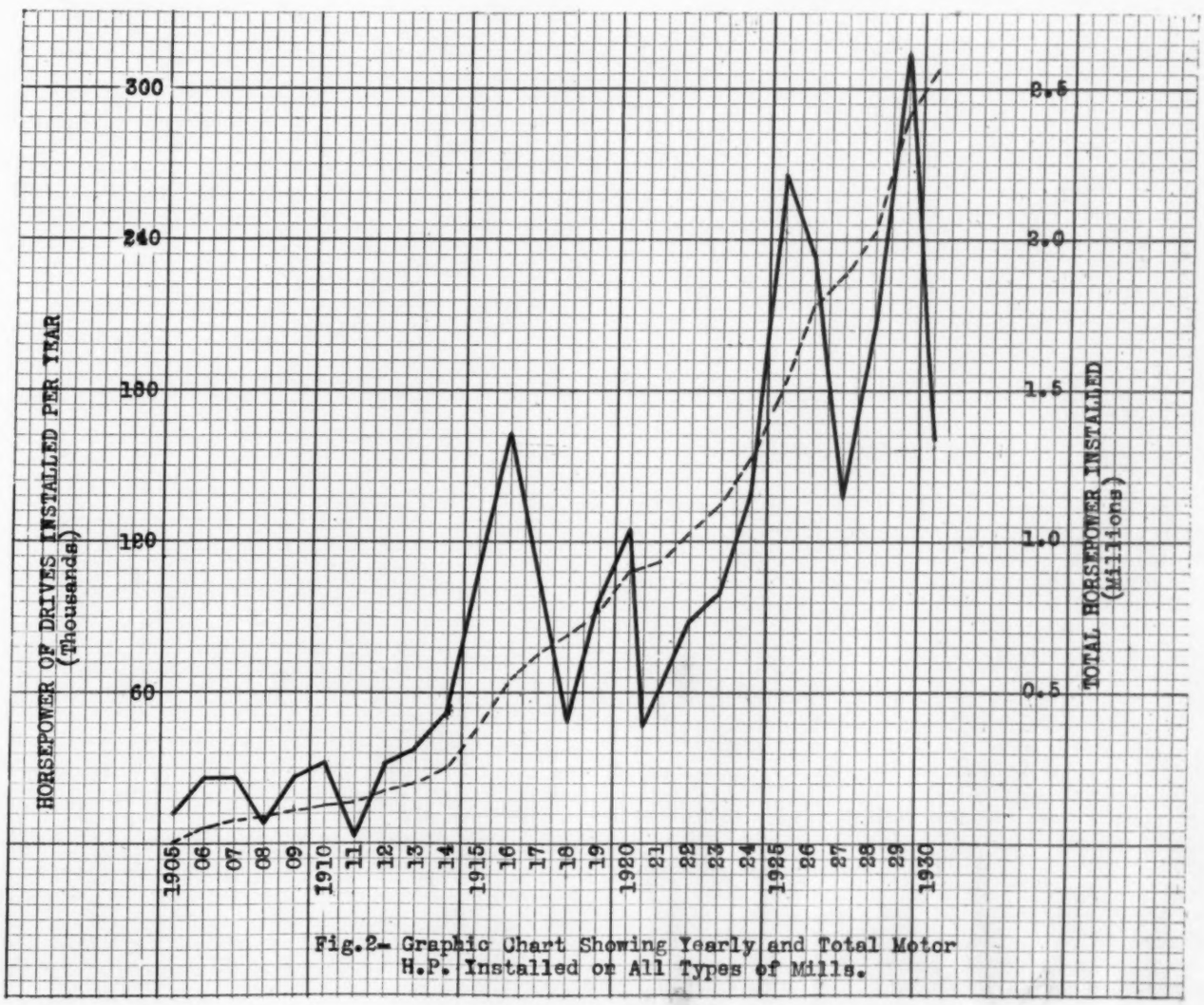


Fig.2- Graphic Chart Showing Yearly and Total Motor H.P. Installed on All Types of Mills.

by nine DC motors, totaling 7,627 HP, is being installed. Some of these motors have a speed range of approximately 5:1, which is obtained partly by motor field adjustments and partly by armature voltage control through the use of auxiliary bucking generators, one for each of the two motors which have this large speed range. The use of these bucking generators permits operating the three main 1750 KW, 600 volt generators in parallel at constant bus voltage. The motors will be equipped throughout with speed regulators of the vibrating type, designed to hold the speed regulation within very close limits.

An 8000 HP, 40-100 RPM reversing motor now under construction is of the single armature type and will develop 2,900,000 lbs. at 1 ft. radius. It is to be used on a 44" Reversing Blooming mill and is the largest motor which has so far been applied to a mill of this size.

Synchronous Motors

It is interesting to note the diversity of application of synchronous motors. Each year sees new application for this type motor which is applicable to most AC drives where no flywheel effect is needed.

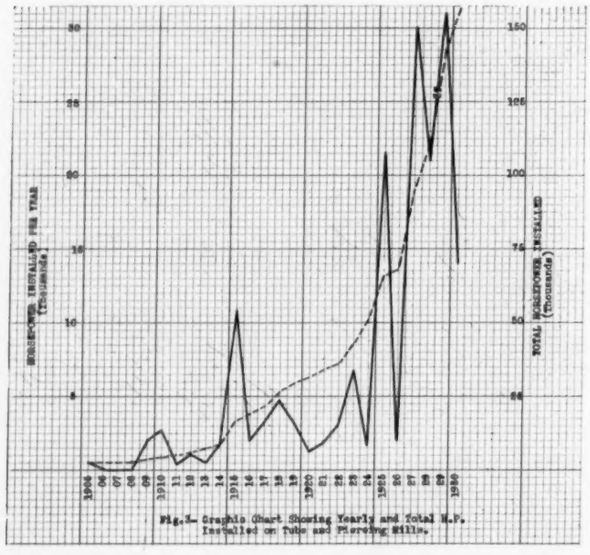


Fig. 3— Graphic Chart Showing Yearly and Total H.P. Installed on Tube and Piercing Mills.

Among the more important synchronous motors which have been purchased during the year may be mentioned two 4500 HP, 156.5 RPM, 6600 volt, 60 cycle units which will drive two rod mills, also one 5000 HP, 360 RPM, 6600 volt synchronous motor to drive a 24" Billet mill and one 4000 HP, 360 RPM, 6600 volt synchronous motor to drive an 18" Billet mill at the same plant. This same company put into operation early this year a 3000 HP, 100 RPM, 11,000 volt, 3 phase, 60 cycle synchronous motor, driving a 3-high Billet mill. This motor is of interest not only because it is one of the very few main roll motors operating at over 6600 volts, but also because it is started from rest by connecting directly to the 11,000 volt circuit.

There have been purchased two synchronous motors, one 2000 HP, 300 RPM, and one 1000 HP, 360 RPM which will drive hot tin mills. This is believed to be the first installation of synchronous motors on mills of this character, previous practice having been to use induction motors with flywheels. Synchronous motors were chosen because of the necessity of maintaining a good power factor in order to earn a low rate on the purchased power and also because of the gain in efficiency. Not only is the synchronous motor itself more efficient than the corresponding induction motor, but the friction and windage losses of the usual flywheel and the

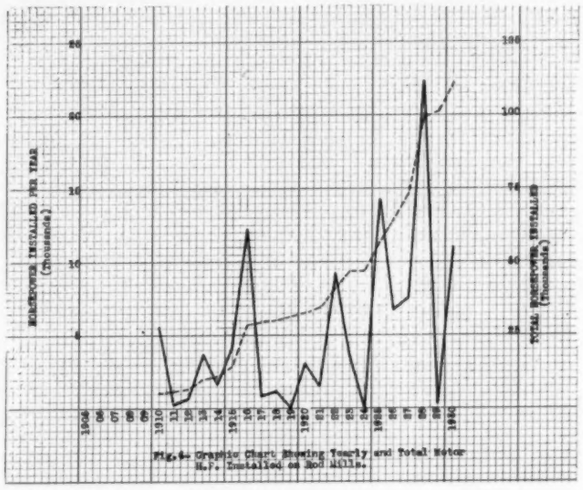


Fig. 4— Graphic Chart Showing Yearly and Total Motor H.P. Installed on Rod Mills.

power losses in the secondary resistor or liquid slip regulator are eliminated. It is expected that the power per ton of tin plate rolled will be at least 5% to 10% less than if an induction motor flywheel drive had been used.

If it is possible to reduce cost of power used in rolling tin plate as has been predicted 5 to 10%, many changes in the type drive on tin mills will be made in the next few years.

Mercury Arc Rectifiers

Mercury arc power rectifiers installations increased both in number and capacity the largest

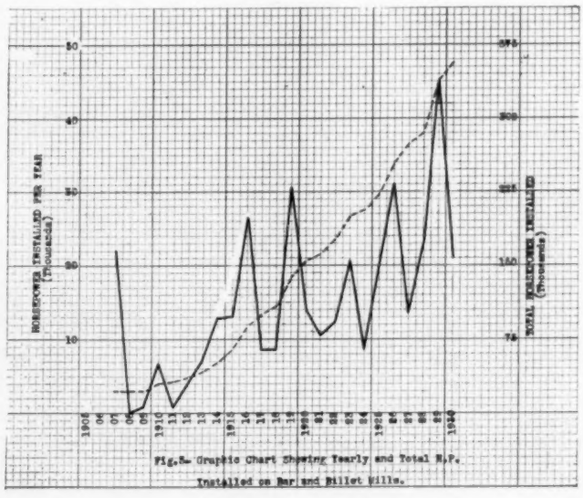


Fig. 5— Graphic Chart Showing Yearly and Total H.P. Installed on Bar and Billet Mills.

unit produced being rated 6500 KW, 650 volts, 10,000 amps. It was designed for use in the production of electrolytic-hydrogen. One railroad applied power rectifiers in all of its substations as the sole source of the supply of energy to its feeder system. This was the first exclusive use of this apparatus for this class of service.

Oil Circuit Breakers

A new principle of scavenging arc products in oil circuit breakers was announced during the year which owes its efficiency to careful provision for a scavenging jet of oil driven by the gas pressure from one break in the circuit, and which displaces

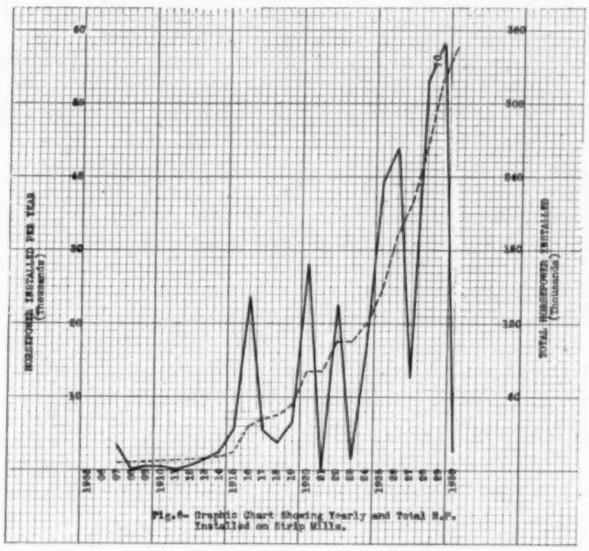


Fig. 6- Graphic Chart Showing Yearly and Total H.P. Installed on Strip Mills.

the arc in the space between the electrodes and another break in the circuit.

Three contacts are used in the new type of breaker, instead of two as in older forms. One, the uppermost, is a fixed, butt contact; the second, just below it, is a floating contact; and the third, the lowermost, is a movable hollow contact. In the closed position of the breaker, current is carried by

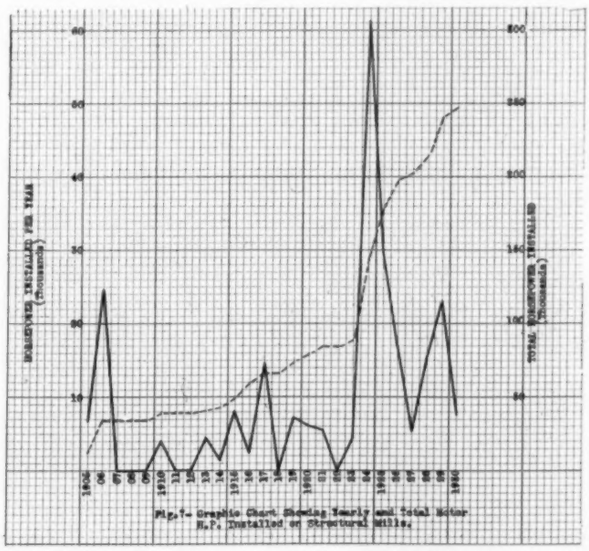


Fig. 7- Graphic Chart Showing Yearly and Total Motor H.P. Installed on Structural Mills.

these three members firmly pressed together. When the breaker is tripped, the floating and hollow contacts start down, driven by the opening springs, thus drawing a short arc between the two uppermost contacts. This arc forms gas and places the oil in the explosion chamber under considerable pressure for which there is very little relief until the floating contact reaches its stop. A secondary break then occurs between the two lowermost contacts and a second arc is drawn between them.

At this point the novelty and effectiveness of the new design are demonstrated. As the oil glides through the passageway in the hollow, lowest contact rod, the lower arc is carried before it and exists alongside it without mixing, and hence with a minimum of loss throughout the current cycle. Then, as soon as the current zero is reached, the arc products are displaced by a smooth flowing wall of solid oil, the dielectric strength of which has not been impaired by carbonization or entrained ionized gas.

Cranes

The following comparison of data on cranes installed and equipment used will show the trend in crane development. During the year 1930, the total number of main roll drive motors installed was only 44% of the number installed during the previous year and on the same basis of comparison, the number of cranes sold to the Iron and Steel industry was 46% of what it was the previous year.

The ratio of cranes totally equipped with anti-

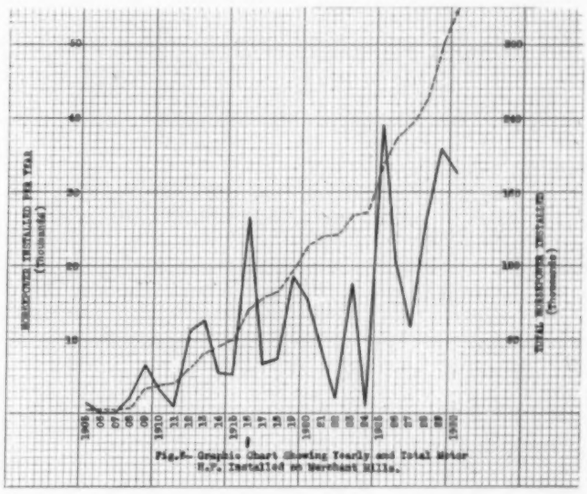


Fig. 8- Graphic Chart Showing Yearly and Total Motor H.P. Installed on Merchant Mills.

friction bearings to the total purchased during the year 1929-30 increased from 50% to 55%. On the same basis, those partially equipped increased from 20% to 25%, leaving a decrease of from 30% to 20% in the use of plain sleeve bearings.

These percentages, though not exact, show clearly the trend in the use of anti-friction bearings.

The use of totally welded cranes is also increasing and some radical departures from conventional crane designs are now being installed and will be watched with no little interest during the coming year.

Cranes built of aluminum and its alloys have been in use, but only recently has this material entered the Chain Hoist field. Some of the many features of this new AL-LITE hoist include lightness, strength, portability, easy accessibility, planetary gearing, and high efficiency.

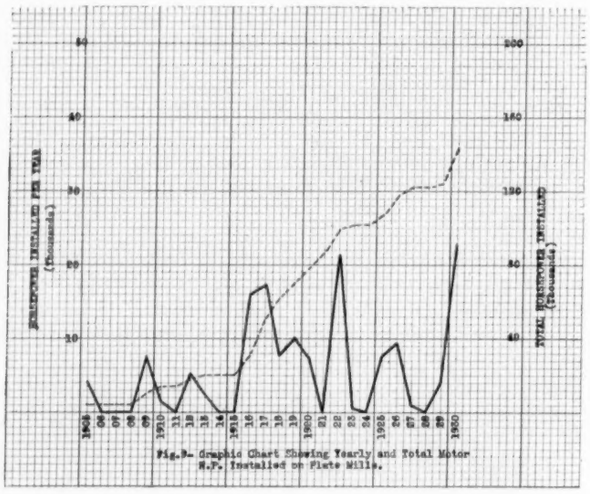
An interesting and unique application of alternating current motor equipment has just been made in connection with a Wellman mule haulage built for the Koppers Construction Company for placing railroad cars on the cradle of a revolving car dumper.

This mule haulage is designed for operating on a 15% grade placing 20 cars per hour on the dumper

cradle, the maximum capacity of the cars being 320,000 pounds loaded weight.

This electrical equipment operates the mule automatically as follows:

The mule is brought out of the pit by the torque motor alone, running at its high speed or 150 ft. per minute for the mule. At the proper point the torque motor is decelerated to 50 ft. per minute to


HORSEPOWER INSTALLED PER YEAR (Thousands)
TOTAL HORSEPOWER INSTALLED (Thousands)
1906 07 08 09 1910 11 12 13 14 1915 16 17 18 19 1920 21 22 23 24 1925 26 27 28 29 1930
Fig.9- Graphic Chart Showing Yearly and Total Motor H.P. Installed on Plate Mills.

engage the railroad car. The deceleration is accomplished by changing to the low speed winding of the torque motor. At this time the main motor is put on the line with all of the secondary resistance inserted. After the car has been engaged by the mule, the torque motor is taken off the line and the main motor automatically accelerated to full speed or 300 FPM of the mule.

The mule is slowed down as the car approaches the car dumper by inserting resistance in the secondary of the main motor and the torque motor is put on line with the high speed winding. Thus the car is placed on the cradle of the car dumper at 150 FPM. The slow-downs and stops are automatically controlled by limit switches or by the master switch.

Control

Perhaps the most interesting development from the standpoint of future possibilities was the greatly increased application of electronic tubes for purposes other than radio communication. Their remarkable versatility in rectifying, converting, inverting, regulating, measuring and control has resulted in numerous applications in substation for electro-mechanical methods of current control.

These controllers provide a very sensitive and positive means of control which is entirely independent of mechanical contact with the moving parts of a machine or the material being produced.

While at first thought, it may appear that a steel mill is no place for so fragile a device as a vacuum tube, still we must not forget that for some years, these tubes have been found to be reliable and rugged enough for automatic train control service. Now they are beginning to find their way into the mills.

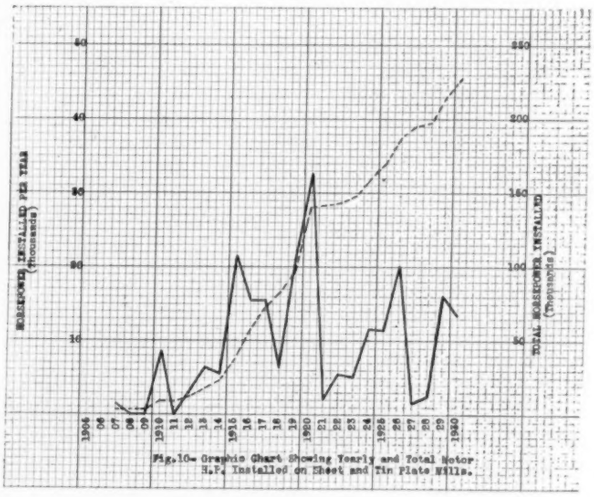
For example, photo-electric tubes are now in successful use on a pipe facing machine in a large tube mill. Each facing machine has two movable cutting heads. When a length of pipe is clamped in position in the machine, these two heads must advance to within ¼" of the end of the pipe and stop there. The heads are motor driven. Obviously, any type of mechanically operated limit switch mounted on the head and actuated by contact with the end of the pipe was out of the question, as the switch would be in the way of the cutting tool after the head was brought to a stop. Consequently, photo-electric tubes were used, a tube and a light source being mounted on each cutting head in such a way that as the head approaches the pipe, the end of the pipe intercepts the beam of light between the source and the photo-electric tube. Shutting off the light de-energizes the tube, which in turn causes the control equipment to stop the travel motor, when the head is ¼" from the pipe.

It seems probable that the photo-electric tubes will prove very useful as limit switches and in other ways. They are also used to turn lights on and off, depending on the amount of daylight available.

Another tube which possesses great possibilities is the Thyratron tube. Its striking characteristics are the greatly decreased amount of power required to heat the cathode, and a marked reduction in the voltage drop which is characteristic of the high vacuum tube. This is brought about by the introduction of a very slight amount of gas or vapor into the bulb.

A Thyratron tube built to about the same size and costing the same amount as the Radiotron will handle approximately 50 times the current.

These are the reasons which give complete faith in the application of the Thyratron type of tube in the broad industrial engineering field to the same amazing extent that the high vacuum type of tube,


HORSEPOWER INSTALLED PER YEAR (Thousands)
TOTAL HORSEPOWER INSTALLED (Thousands)
1906 07 08 09 1910 11 12 13 14 1915 16 17 18 19 1920 21 22 23 24 1925 26 27 28 29 1930
Fig.10- Graphic Chart Showing Yearly and Total Motor H.P. Installed on Sheet and Tin Plate Mills.

developed around the pliotron idea, has dominated the radio communication and broadcasting field.

Speed Matching of Pin and Hook Conveyors

Products that are coiled on a 10" Bar mill now being installed are to be conveyed first on a pin conveyor and then to a second or what is termed as a hook conveyor. The transfer of these coils from the first to the second conveyor is to be accomplished without interrupting the running speed of conveyors and it is also imperative that the pins of

the pin conveyor and hooks of the hook conveyor are in their relative positions.

The control to accomplish this will be of the Differential Selsyn Photo-electric cell principle, which is herewith briefly described.

The Selsyn transmitters, of which there are two (one coupled to the pin and the other coupled to the hook conveyor) have a 3 phase stator winding, similar to that of an induction motor, and a rotor with definite poles, excited from alternating current. If the stators of two Selsyns are electrically connected and their rotors excited from the same source, the two rotors will assume a fixed position and if one rotor moved, the other rotor, if free to turn, will exactly follow the movement of the first rotor. The differential Selsyn has a 3 phase winding on both stator and rotor, and if a differential Selsyn is introduced into the circuit between two Selsyn transmitters (that is, if the stator of the differential Selsyn is connected to the stator of one transmitter and the rotor of the differential Selsyn to the stator of the other transmitter) it will act as an electrical differential and the angular movement of its shaft will correspond to the difference in the angular movements between the two transmitters, or, if the shaft of the differential Selsyn is turned manually, the synchronizing position of the two other Selsyns may be varied to anything between 0 and 360 degrees displacement on these two Selsyns. Photo-electric cells are then used to bring about the corrective action, which is accomplished by motor driven rheostats.

Lightning Arresters

Lightning is still the arch enemy of uninterrupted electric service but laboratory and field investigations with improved recording instruments added greatly to the knowledge of the character-

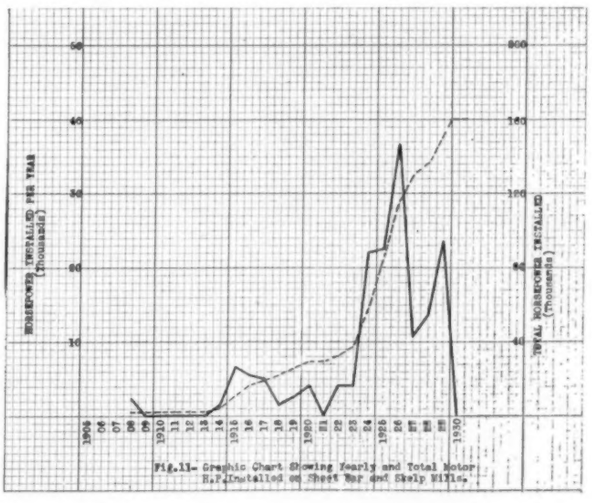


Fig.11- Graphic Chart Showing Yearly and Total Motor H.P. Installed on Sheet Bar and Skelp Mills.

istics of lightning during the year, while the development of Thyrite material made it possible to utilize the data so secured in a practical way for power system protection. The Thyrite lightning arrester has already been installed on systems operating at the highest commercial voltage.

The lightning-stroke recorder and the surge indicator together have given the first positive proof, in definite and exact terms, of the pragmatic worth of the overhead ground wire long urged as a result of early laboratory tests. On a certain high-voltage line, about 20 direct strokes were recorded and the data shows that the ground wire is useful in protection against both induced voltages and direct strokes. Checking the mathematical work, the ground wire was shown to be effective against direct strokes when the footing resistance is low.

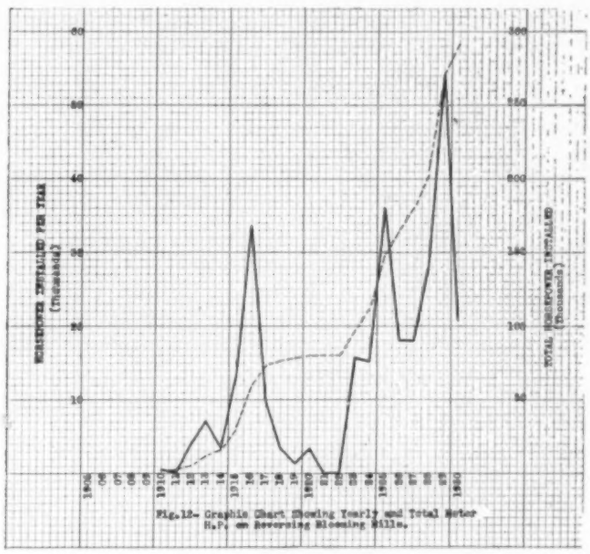


Fig.12- Graphic Chart Showing Yearly and Total Motor H.P. on Reversing Blooming Mills.

A most complete mathematical study of the ground wire made during the year further indicates the beneficial effect of the ground wire as a positive means of reducing flashovers and outages on transmission lines.

Other laboratory work included studies and recommendations for the protection of various structures from lightning, including oil reservoirs and large explosives plants and warehouses.

Auxiliary Motors

What is believed to be the first application of a synchronous motor to shear drives was in connection with a "flying" shear which is used to cut accurately to length the steel delivered from a hot-strip mill. The steel may be delivered from either one of three mill stands; and in order that the cuts may be held accurately to length, it is essential that the shear drive be synchronized with the delivery stand. Therefore, there is mechanically connected to each delivery stand a synchronous generator, which may be used to furnish power to the synchronous motor on the flying shear.

In the past it has been usual to drive the shears which are used to cut heavy steel bars by means of induction motors equipped with flywheels. The motors and wheels run continuously and a clutch is employed to operate the shear. Mechanical clutches are none too satisfactory and during the year several installations were made using direct-current motors to drive the shear; the motors starting and stopping for each cut, thus eliminating the clutch. One such installation is on an 800-ton slab shear, which is designed to cut simultaneously three 8-in. by 8-in. steel blooms. The shear is driven by two 200 HP direct-current motors; and tests indicate that with the drive and control employed the shear can make a

maximum of 14 cuts per minute, starting and stopping for every cut.

Improved electrical characteristics and noiseless operation are features emphasized in introducing herringbone rotors for motors of from 1 to 50 HP capacity. The rotor bars instead of being straight or skewed are formed in shapes similar to the tooth in a herringbone gear. Their use in motors on applications such as fans, direct-connected pumps, is intended to eliminate end thrust, bearing noise, and improve pullout efficiency and power factor.

A variable-speed drive which combines motor, speed changer, speed reducer and control in a single housing has been announced. It is made in sizes to deliver from ¼ to 7½ HP and is recommended for driving feeders, assembly conveyors, mixers, machine tools, and other applications where a variable-speed drive is needed.

The motor section is usually wound to operate at 1200 RPM and the drive will deliver input at any speed between 24 and 144 RPM or 120 and 720 RPM. Output speed is increased or decreased while the machine is in motion by turning the small hand wheel on top of the housing.

Mechanism is enclosed in a single housing, covering all moving parts except the output shaft, thus protecting both machine and operators from possible injury.

Internal Combustion Engine Locomotives

Recent developments in locomotive power transmissions have produced the electric drive which, in combination with gasoline or Diesel engines, places the internal combustion engine type of locomotive on a par with the steam locomotive with respect to mobility, and ahead of the steam locomotive with respect to operating factors as availability for service, economy of operation, safety, visibility, convenience, and general performance. The electric drive has many advantages over the conventional clutch and gear transmission between engine and locomotive axle, in that it is easier to operate, gives better pulling power and superior overall performance on grades, is much easier on the engine, and produces a locomotive of greater general reliability and availability. It is rapidly supplanting the mechanical drive on locomotives weighing between 12 and 25 tons, and is still more widely used on locomotives of 30 tons weight and upwards.

Gasoline-electric locomotives for industrial service are now available over a weight range from 12 to 90 tons, utilizing engine powers from 120 to 600 HP. Diesel electrics range between 30 and 110 tons at present, although this weight range will doubtless be widened in the near future.

Miscellaneous

Rolling mill bearings must operate at high unit pressures, and the selection of suitable bearings is one of the important phases of mill design and construction. Considerable experimental work has been done toward the improvement of the design of the conventional types of babbitt and bronze lined bearings, and a new type of bearing has been introduced by the successful operation of several sets of duck bakelite micarta bearings on rod mills. Bearings of this material require only water for lubrication, they can be made in any required size, the quality is uniformly high, and experience indicates a life of several times that obtained with bronze or lignum vitae.

Conclusion

A great deal has been heard during the past year regarding the effect of modern machinery on the unemployment situation.

It is generally conceded that in no other country do the people as a whole enjoy such a high standard of living and that the development of new processes and new equipment has been responsible in a large measure for this condition.

In the production of these so-called modern developments many of which are now considered necessities of life more labor is employed than was displaced by the introduction of modern machinery.

Credit then should be given where credit is due and no industry has contributed more to this development than the electrical industry.

Each year presents new problems and the staff of skilled Research Engineers who devote their entire efforts to these problems is constantly increasing. To the foresight of those in charge of the organizations who control the policy of the electrical industry and to those engineers who devote their lives to this development work the people of this country are largely indebted for the high standard of living which we as a nation enjoy.

Of necessity, the major portion of this annual report consists of information compiled during the year and it is made possible by the hearty co-operation of the members of the Electrical Developments Committee and the Research Engineers who are connected with organizations serving the Iron and Steel Industry.

MARKED REDUCTIONS IN RAILROAD FARES TO CLEVELAND FOR JUNE CONVENTION AND EXPOSITION

We would ask that as many as possible, traveling via railroads to our June Exposition and Convention, take advantage of the reduced railroad fares accorded our Association by the Central Passenger Association, and through them, to most every railroad in the United States and Canada. Each and every ticket agent on the lines granting this reduced fare have the official tariff sheets on file giving explicit information and they will be very glad to enlighten any of our members making inquiry.

These tickets will be on sale from June 11th to June 17th, inclusive, good for return from June 15th to June 25th, inclusive, at 1½ fare for round trip BUT IT IS ABSOLUTELY NECESSARY FOR EVERY USER TO SECURE FROM OUR ASSOCIATION AN IDENTIFICATION CERTIFICATE IN ADVANCE—this is presented to the local railroad agent after your endorsement and becomes his authority for granting our members and Exhibitors this special rate. This offer is also open and available to all members of your family providing you secure from us the proper certificates in advance.

We have secured a supply of these certificates, subject to your call, and we would suggest that you immediately advise us how many you intend to use and we will send them to you at once.

ASSOCIATION OF IRON & STEEL ELECTRICAL ENGINEERS,
JOHN F. KELLY, Managing Director,
1010 Empire Building, Pittsburgh, Pa.

Research Covering Alternating Current Arc Welding

By GROVER A. HUGHES * and R. C. McBRIDE †

The use of alternating current in metallic and carbon arc welding is not new, having been used many years ago. The writer's attention was first called to it in 1914. At that time, a reactance coil was inserted in Series in an alternating current circuit of 220 volts. The reactance being adjusted so that a desired current would flow when an arc was drawn. Arc welding was in its infancy and Safety rules were not observed as they are today. The Efficiency Department was not inquiring into the cost of welding. The designing engineer did not have data at hand to tell him what he could expect from a weld, fence wire was cheap, electricity plentiful. Labor was about 17½ cents per hour and the foreman had instructions to "put on plenty" and this was the writer's introduction to arc welding in a certain plant near Pittsburgh, Pa.

GROVER A. HUGHES

The plant was using both D.C. and A.C. machines. As mentioned before the A.C. machines had 220 volts open circuit and they were using bare electrodes, acetylene rods and fence wire, and were actually depositing metal.

In a short time, this high voltage (220 volts) was not considered safe and a new type of welder made its appearance on the market. The open circuit voltage was about 125 volts. All worked fairly well with bare wire.

After coated electrodes were developed the A.C. welders would work fairly well with an open circuit voltage of 80 volts.

We now have the alternating current arc welder working with voltages same as direct current and able to deposit metal equally as well with bare and coated electrodes as any direct current machine.

This has been the dream of the Electrical Engineer and Electrician; Maintenance men and Superintendents.

How often we have heard that wish, "Oh, for a welding machine we could move from place to place and just plug in with a pair of wires that would not require the services of an electrician. One that would give good welds."

It was this that led us to investigate the possibilities of alternating current arc welding:

A—Chemical analysis of metal deposited.
B—Rate of deposit.
C—Ductility.
D—Tensile strength.
E—Penetration.
F—Non-ferrous metals.
G—Electrical characteristics.
H—Bare and coated electrodes.

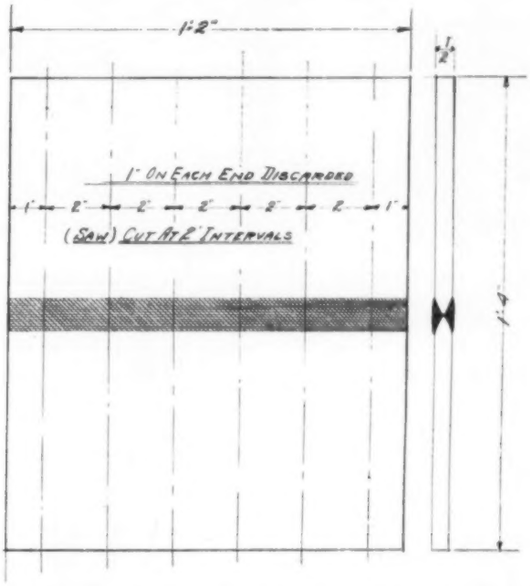


FIG. 1—One-inch each side discarded. Specimens 2-inch wide were accurately cut and weld machined to thickness of plate. One-half inch giving one square inch area.

Fig. 1 shows the method of preparing test specimens. Structural steel meeting the standards of the American Society for Testing Materials used.

Each specimen was butt welded with a double-vee and gave us five test pieces. Welding wire was of standard commercial manufacture. Four grades of wire were used. One man did all the welding. The tests specimens were handed to the welder and he was instructed to weld them as he would in production. Fig. 1A shows specimen after welding. Fig. 1B is a 2" wide specimen ready for testing.

* Electrical Engineer; † Chemist, Truscon Steel Company, Youngstown, Ohio.

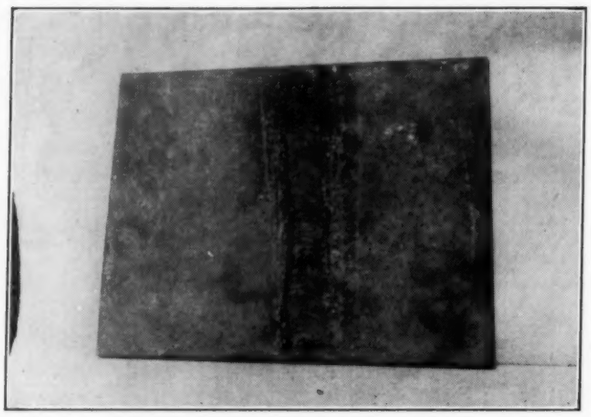


FIG. 1-A—Specimen after welding.

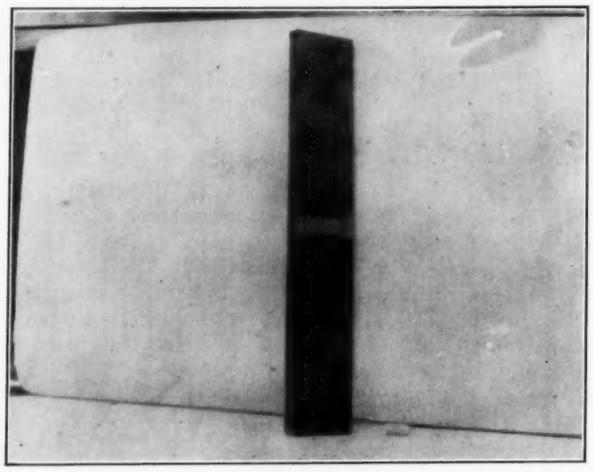


FIG. 1-B—One of the two-inch by one-half inch pieces ready for testing.

The following is the result of this investigation:

Metal deposited with A.C. Welder 180 Amps. Bare Electrodes five thirty-seconds inch diameter. All tests pulled at 1/8" per minute.

Electrode	Deposited	Ultimate Max.	Tensil Min.	Lbs. per sq. ave.
No. 1 Carbon .13	.06	55700	33850	44850
Mang. .45	.32			
No. 2 Carbon .18	.07	55300	35700	49200
Mang. .60	.37			
No. 3 Carbon .30	.07	62700	45400	50800
Mang. .80	.61			
No. 4 Carbon .50	.10	72000	50400	56430
Mang. 1.30	.91			

We were surprised at the large amount of Manganese in the weld metal.

Metal deposited with coated electrode 3/16" diameter deposited with 150 amps.

Carbon in rod	.08
Mang. in rod	.55
Carbon in coating	4.50
Mang. in coating	8.00

(Spiegeliesen) Ferro Mang.

Deposited in weld:

Carbon	.60
Mang.	4.50

(Would scratch glass)

This rod was not tested for maximum tensile strength.

A second series of tests was run to compare a coated electrode with bare electrode. Analysis of coated electrode:

Diam. .155

Carbon .12 mang. .45 Phos. .04 Sul. .03 Sil. .06

Coating was titanium oxide. Sodium carbonate and metallic manganese. Deposited with 180 amps.

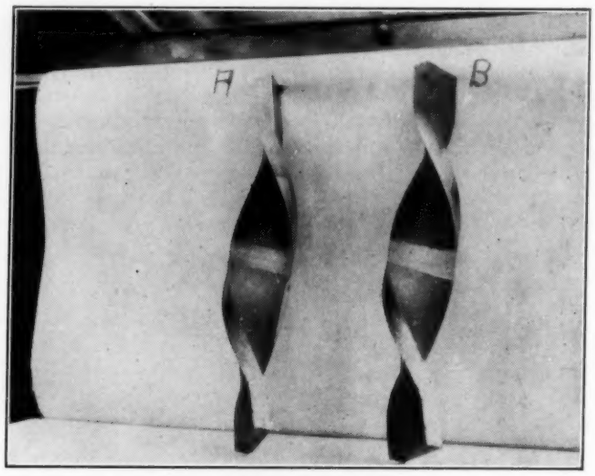


FIG. 2—"A" was welded with coated Electrode. "B" welded with bare Electrode.

Bare electrode: Diam .156 Car. .135 Mang. .68 Phos .020 Sul .018 Sil .012. Deposited with 200 amps.

Following results were obtained:

Coated Electrode	Ultimate Max.	Tensile Min.	Strength Sq. Ave.
Deposited Car. .11	66270	59630	63050
Mang. .22			
Bare electrode			
Deposited Car. .07			
Mang. .32	66050	55730	61830

Twenty-eight percent more coated electrode was required for welding specimen than was required for bare electrode.

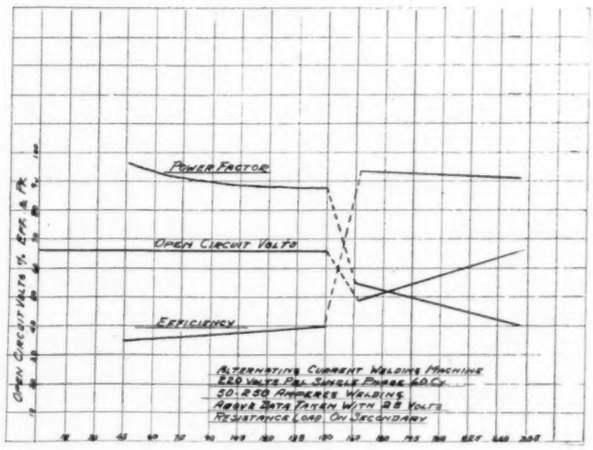


FIG. 3.

One test piece of each of the coated electrode and bare electrode was twisted through 200 degrees

TABLE 1

ALTERNATING CURRENT WELDING MACHINE 220 VOLT PRIMARY, SINGLE PHASE, 60 CYCLE 50-250 AMPERES WELDING. ALL TESTS MADE BY HAND.

Test No.	Mat'l Used	Type Weld	Welding Amps.	Hrs. per lin. in. of weld	Weld Position	Bare E-1-A Elect'de	Watts Input	Arc Volts	% Eff. Welding
1	3/8" H.R.S.	Lap	210	.0067	Hor.	5/32"	4800	18.5	81
2	"	Rein. V	216	.0076	"	"	4950	17.8	78.5
3	"	"	184	.0105	"	"	3750	17.5	86.
4	"	"	180	.0146	Vert.	"	3810	18.5	87.5
5	"	"	208	.0117	"	3/16"	4890	21.5	91.5
6	1/4" H.R.S.	Lap	208	.0040	Hor.	5/32"	4740	18.5	81.2
7	"	Rein. V	216	.0056	"	"	4650	17.5	81.3
8	"	"	226	.0071	"	"	4560	19.	94.
9	3/8" H.R.S.	"	204	.0126	"	"	5040	20.5	83.3
10	"	"	216	.0124	"	"	5100	20.	84.7
11	"	"	180	.0143	Vert.	3/16"	4050	19.	83.5

and in both cases weld was not fractured. Fig. 2 shows the pieces after testing.

Another series of tests was run in which the electrical characteristics of the welding machines were tabulated and recorded in Table 1. This table shows welding speeds, energy input, arc voltage efficiency in horizontal and vertical welding.

Table 2 is of mechanical tests of weld in Table 1.

MECHANICAL TESTS OF TESTS NOS. 2, 4, 8 AND 11, TABLE 1

Test specimens were made up in plate form, each plate being cut into 4 test samples, representing a group of welds made under the same conditions.

Description	Ult. Ten. Str. Lbs. Inches Sq.
Avg. of all tests—16 samples	49,524
Avg. of highest group—4 samples	52,862
Avg. of lowest group—4 samples	47,525
Highest test sample	55,250
Lowest test sample	45,600
Avg. of vertical tests—4 samples	52,862
Avg. of horizontal tests—12 samples	48,409
Highest vertical weld	55,250
Lowest vertical weld	50,400
Highest horizontal weld	53,000
Lowest horizontal weld	45,600

Figure 3 shows the operating characteristics of a commercial A. C. welder which has been recently improved to the point that both the average efficiency and power factor compare very favorably with those of commercial direct current equipment involving an induction motor driven direct current generator of comparable ampere capacity.

The break in the performance curves occurs at the point where the control is changed from a combination of reactance and resistance to straight reactance control.

This machine requires approximately 300 watts for no load operation. This low no load requirement is quite valuable as it increases the all day efficiency of the machine and results in a much lower operation cost, since it is estimated that a welder welds but about fifty per cent of the time, the remaining being taken up in changing electrodes, moving to a new location, etc.

Figure 4 is a reproduction of a number of oscillograms showing the instantaneous performance characteristics of the A.C. Welder, when used with two different electrodes.

Fig. 4. Group A clearly shows the quick return to normal operation from short circuit. The arc was shorted for 4 cycles as shown by the low secondary or arc voltage.

Group B shows the characteristics when welding with a heavily fluxed electrode, the two oscillograms are quite similar, both in wave form and continuity through the zero value of arc current.

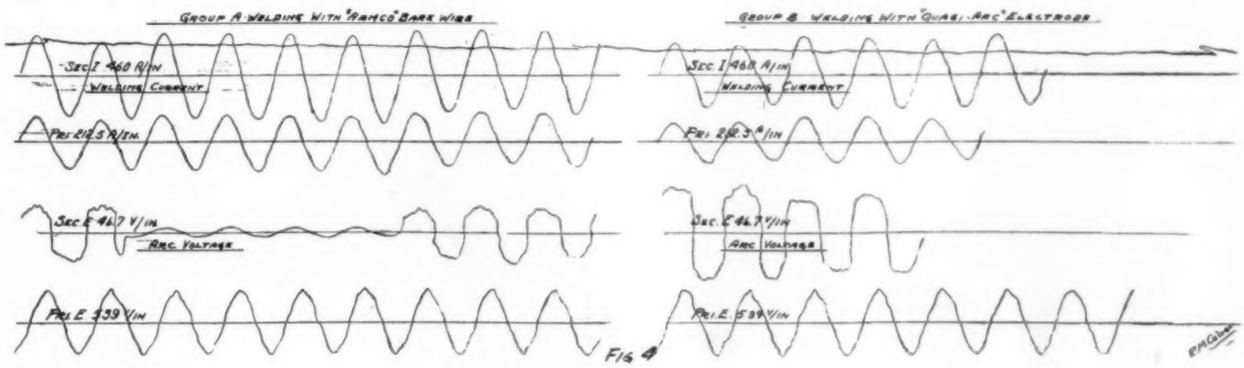


FIG. 4.

In welding cast iron, we experienced no more trouble than welding with direct current. Weld was apparently same as with direct current in every respect. Same electrodes were used and same methods employed. Cast Iron Specimens were preheated to a dark red temperature. After welding the work was again brought to a dark red temperature. Welds were as good as could be expected with cast iron, and in the writer's opinion are uncertain at best. Test specimens were four inches wide and one and one half inches thick.

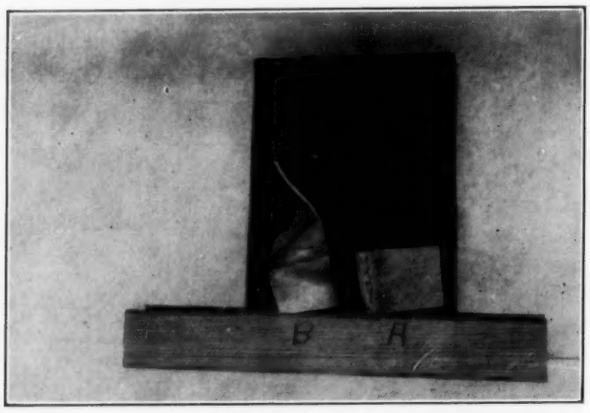


FIG. 5—Aluminum welded with ⅛" Electrode 120 Amperes. "A" bent under Hammer. "B" Twisted.

ALUMINUM

Our experimental work with the A. C. welder on aluminum was on the Aluminum Company of America 2-S material. The electrodes used were purchased from the Williams Company of Greensburg, Pa. The electrodes were ⅛" in diameter and coated. The coating contained ammonium chloride and sodium silicate.

SUMMARY OF TENSILE TESTS

Thickness	Material	Specimen	Percent elongation 8"	Tensile Strength lbs. per square
⅛"	2-S	original	36.5 (max)	14450 (max)
⅛"	2-S	original	29.4 (min)	13120 (min)
⅛"	2-S	original	33.4 (ave)	13840 (ave)
⅛"	2-S	welded	31.3 (max)	13010 (max)
⅛"	2-S	welded	28.3 (min)	12140 (min)
⅛"	2-S	welded	29.6 (ave)	12365 (ave)
¼"	2-S	original	37.1 (max)	14620 (max)
¼"	2-S	original	34.2 (min)	14150 (min)
¼"	2-S	original	35.4 (ave)	14260 (ave)
¼"	2-S	welded	32.0 (max)	13340 (max)
¼"	2-S	welded	28.1 (min)	12040 (min)
¼"	2-S	welded	29.3 (ave)	12410 (ave)

Fig. 5A shows a piece of aluminum welded with the A.C. Arc Welder bent double under the hammer.

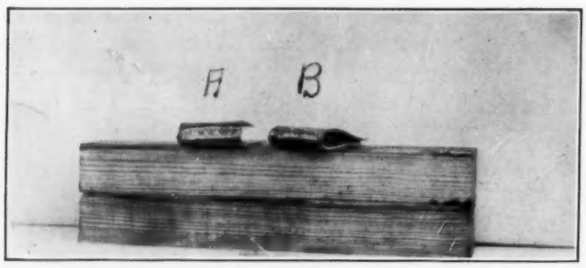


FIG. 6—"A" Enduro KA2. "B" Ascoloy.

Fig. 5B is a piece of aluminum twisted through 200° after welding.

ENDURO KA-2

The only Enduro KA2 available was 16 gauge. Ultimate tensile strength was not taken. Enduro coated Rods were used ⅛" diameter. Ultimate tensile strength after welding not determined.

Fig. 6A shows a piece of Enduro KA2 bent double under the hammer after welding and grinding weld to thickness of original plate. Fig. 7A shows Enduro KA2 twisted through 200°.

Fig. 8A shows Enduro KA2 welded to steel. 8B Ascoloy welded to steel.

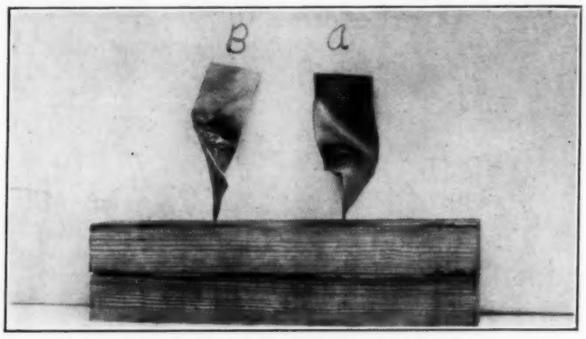


FIG. 7—"A" Enduro KA2. "B" Ascoloy.

ASCOLOY

Fig. 6B shows Ascoloy welded with the A.C. machine and Enduro KA2 coated electrode. This was bent double under the hammer.

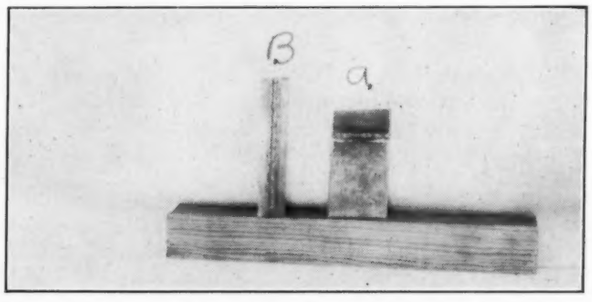


FIG. 8—Enduro KA2.

MONEL METAL

The only monel metal available was ⅛" sheets. This was welded with ⅛" coated electrode. Coating on electrode was ferro-titanium and calcium-silicon. Sufficient monel metal was not available to make complete investigations of the A.C. welder and time

FIG. 9—Copper deposited on Steel.

would not permit us to procure more. The maximum tensile strength obtained was 42,380 pounds per square

inch. As this was the first experience of the operator with monel metal, he did not have a perfect fusion full length of the six inch seam and all indications were that after a little practice, he could easily obtain better than 50,000 pounds per square inch.

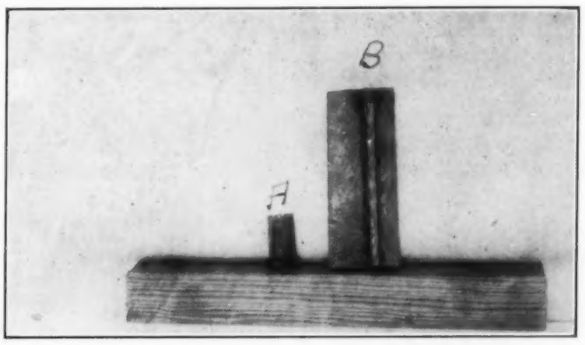


FIG. 10—"A" Two pieces of .019 Steel welded with A.C. welder Bare Electrode.
"B" Note smooth bead deposited with the A. C. Welder.

COPPER

This A.C. welder worked so well with the Enduro KA2 and Ascoloy and aluminum we wondered just what could be done with it in the way of depositing various non-ferrous metals. A piece of No. 6 B&S gauge hard drawn copper rod was coated with the following coating:

Shellac commercial liquid	2 oz.
Alcohol	2 oz.
Calcium Carbonate	2 oz.
Silica Flour	2 oz.
Sodium Bicarbonate	1 oz.
Titanium Oxide	1 oz.

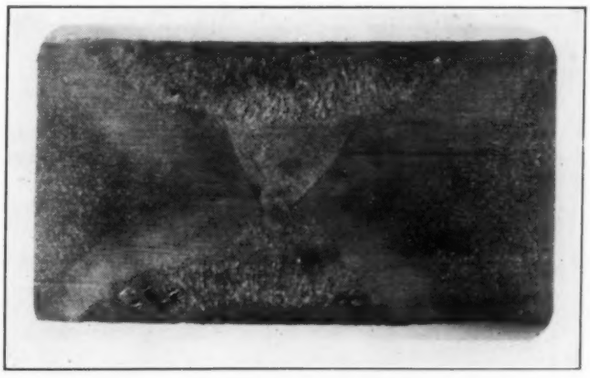


FIG. 11—Photomicrograph of one-half inch plate and weld 10 diameters of Fig. 2.

Figure 9 shows a piece of steel with two beads deposited and cut through the bead and polished, note the penetration. This depositing of copper opens new fields and great possibilities.

We then experimented with the same copper electrode using same coating to deposit copper on copper. The results were not as satisfactory as desired and the coating was changed with some degree of success but as yet, not entirely satisfactory. The results obtained were such that we believe we will soon be able to deposit copper as well as aluminum.

Shown in Figure 10 are (A) two pieces of .019 steel welded with AC Welder Bare Electrode. In (B) note the smooth bead deposited with the AC Welder.

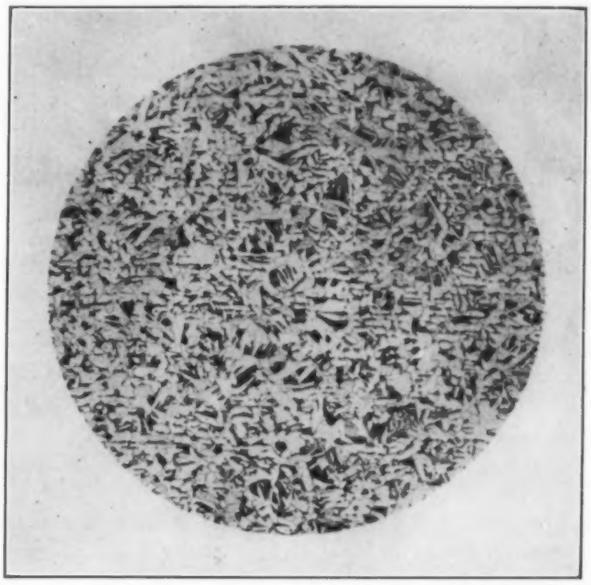


Fig. 11-A—Photomicrograph of parent metal of Fig. 2. 100 Diam.

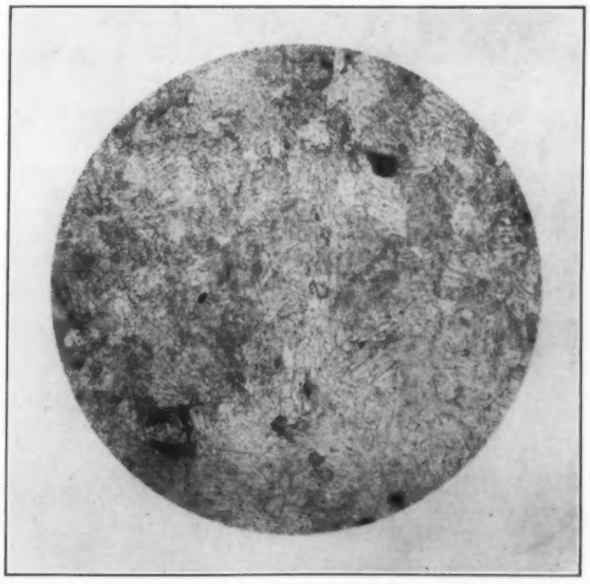


FIG. 11-B—Structure of deposited metal of Fig. 2. 100 Diam.

Figure 11 shows photomicrograph of one half inch plate and weld 10 diameters of Figure 2.

Figure 11a shows photomicrograph of parent metal of Figure 2, 100 diameters.

Figure 11b shows structure of deposited metal of Figure 2, 100 diameters.

Figure 12 shows the half inch test specimen bent under the hammer 100 degrees, shows no sign of fracture in weld. Welded with Bare Electrode.

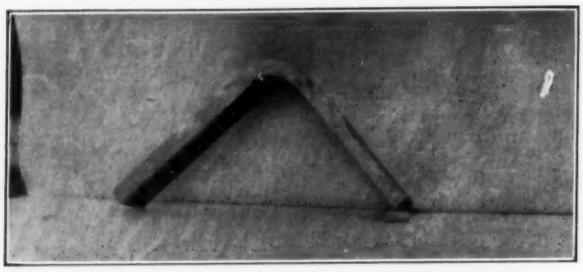


FIG. 12—One-half inch test specimen bent under the hammer 100° shows no sign of fracture in weld. Welded with bare Electrode.

CONCLUSION

Alternating current for arc welding is satisfactory as to tensile strength, ductility, rate of depositing metal and current consumption. Efficiency of welder is high and voltage and current curves are ideal.

Satisfactory welds can be made with bare electrodes.

Satisfactory welds can be made with non-ferrous metals.

We do not state that alternating current is superior to direct current, but do state that alternating current arc welders are as good and are practical and have their place in industry.

Twin Motor Drive

By R. H. WRIGHT* and H. E. STOKES*

The recent development of the twin-motor drive for main rolls is a logical step in the modern trend toward greater mechanical simplicity of rolling mill machinery. The term "twin motor" has come to refer to a form of rolling mill drive in which each one of a pair of rolls is independently driven by a separate motor. In a true twin-motor drive the motors may not operate at exactly the same speed at all times nor do they depend entirely on the coupling effect of the metal being rolled to maintain correct load division and speed relations. Independent drive for the working rolls had been used for wheel and tire mills, piercing mills, and tube expanders and reelers. In these installations the motors rotated in one direction only at practically constant speed and the metal between the rolls provided an effective coupling and rather definitely fixed the speed and load relations.

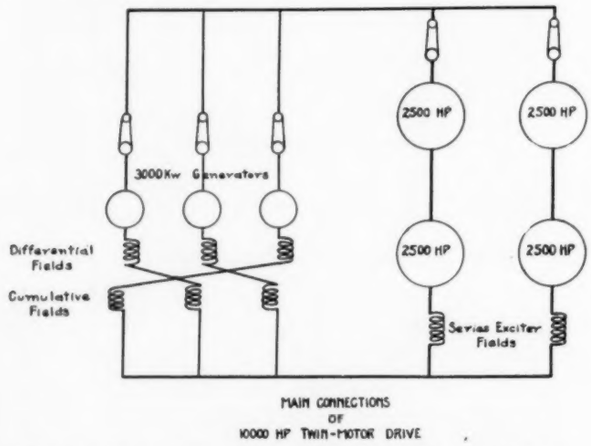


FIG. 1—Main connection diagram—10,000 h.p., twin-motor drive.

Reversing beam mills with independently driven edging rolls were also in successful operation. Experience with beam mills demonstrated that the speed relations of two reversing motors working on the same piece of steel could be adjusted to take care of varying drafts with no indications of unusual roll slippage. This experience therefore formed an important step in the development of the twin motor drive. The demand for more and more power for heavy blooming and slabbing mills increased the difficulty of designing both the mechanical and electrical parts of the main drive along conventional lines and made it highly desirable to make drastic changes in the form of the drive. So now a 54" blooming mill and a 44" slabbing mill, each with main rolls driven by independent motors are in successful operation.

When the electrical equipment for the 54" blooming mill first came under consideration it was felt that the continuous capacity and maximum torque of the reversing motor should be greater than any-

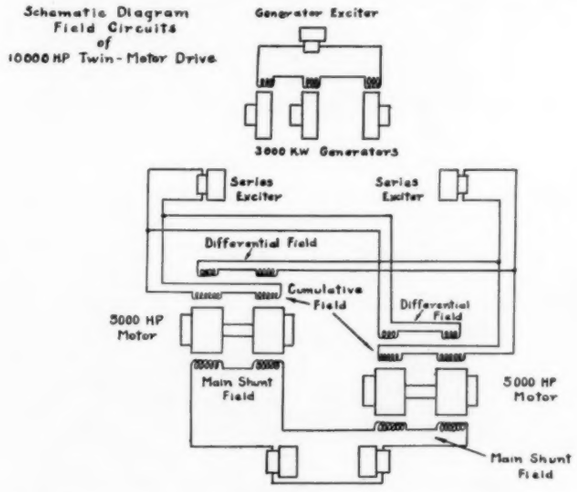


FIG. 2—Field circuit diagram—10,000 h.p., twin-motor drive.

* Engineering Dept., Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

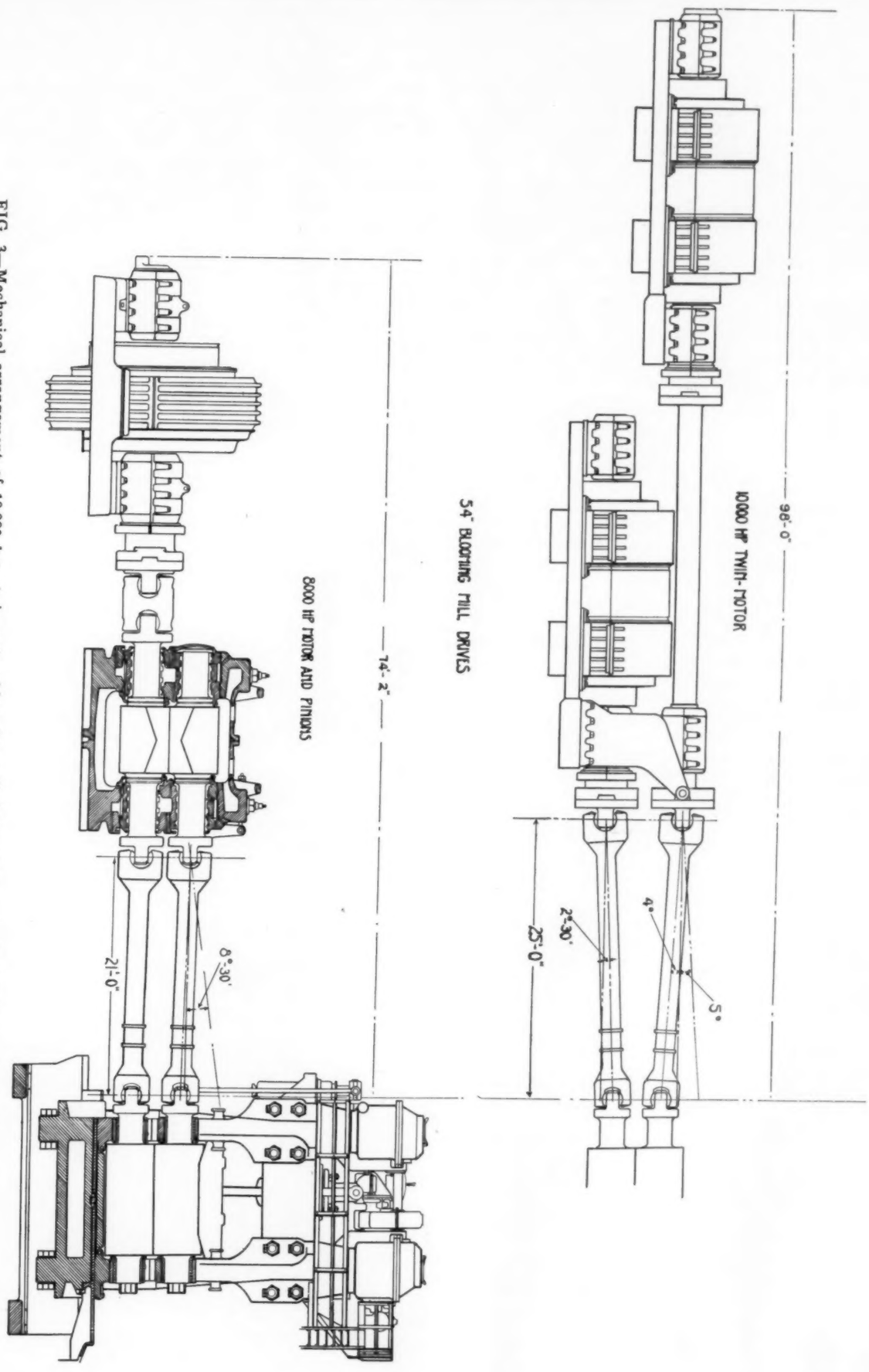


FIG. 3—Mechanical arrangement of 10,000 h.p., twin-motor blooming mill drive compared with 8,000 h.p., pinion drive.

thing which had been used previously, to provide power to roll heavier sections at higher tonnage rates. Accordingly both 10,000 hp. and 12,000 hp. equipments with maximum torques of 3,940,000 pounds feet and 4,725,000 pounds feet respectively were considered. A previous duplicate mill had been equipped with an 8000 hp., 40 rpm. drive with a rated maximum torque of 2,500,000 pounds feet. For the higher motor torques it was thought that the drive for the new mill could be improved mechanically by eliminating the mill pinions. The mechanical improvement has been realized, but other advantages of the twin motor drive such as greater flexibility, greater ease of handling, lower motor inertia, higher average rolling speed and greater tonnage output so far outweigh the expected advantages that they now seem insignificant. This, of course, is the usual history of many developments.

The design of reversing equipments for continuous capacities of 10,000 hp. and 12,000 hp. at 40 rpm. and good for maximum torques approaching 4,000,000 and 5,000,000 pounds feet respectively presents some interesting problems. A motor with a single unit armature would have advantages on account of its simplicity and comparatively high efficiency. The maximum capacity which has so far been built with a single unit armature is 8000 hp. at 40 rpm. One such motor has an armature diameter of 180", which is about the maximum diameter which can be shipped in one piece. Using present design proportions about 10,000 hp. continuous capacity at 40 rpm. with 3,300,000 pounds feet maximum torque is the largest motor which could be built with a single unit armature. The inertia of such a motor would be 230% of that of the 10,000 hp. twin-motor drive finally adopted. So, while theoretically it may be possible to build single unit motors for much greater capacities than are now required, practical considerations such as shipping space and inertia rather definitely fix the limits of capacity which can be built in one armature.

A double armature motor offers the best possibilities for a single machine of 10,000 or 12,000 hp. capacity at 40 rpm. With a double armature motor of this rating it is necessary to decide whether to use three generators or four generators and which one of four or five possible schemes of main connections should be employed. Even with a double armature motor the inertia is nearly twice that of a twin-motor drive.

So it will be seen that the construction of the electrical equipment for a high capacity reversing drive is somewhat more complex than for small and medium ratings.

Pinion stands suitable for transmitting torques of 4,000,000 to 5,000,000 pounds feet become very large and heavy and their design and manufacture involves serious mechanical problems. The twin-motor drive therefore offered both mechanical and electrical advantages.

The twin-motor drive finally selected for the 54" blooming mill consists of two 5000 hp. 40/80 rpm. double armature motors with a combined maximum torque rating of 3,940,000 pounds feet. Each armature is wound for 350 volts and the two armatures of one motor are connected in series, as shown in the diagram of main connections, Figure 1. The two motors operate in parallel and receive power from three 3000 kw., 700 volt generators, connected in parallel. The motor generator has a 90-ton, 15-foot diameter steel plate flywheel and is driven by a 6500 hp., 368 rpm. induction motor.

The field circuit diagram, Figure 2, shows the system of field control. The shunt fields of each double armature motor are connected in series and in turn connected in series with the shunt field of the other motor, thus insuring the same shunt field excitation for both motors. Two shunt field exciters were employed for the motors in order to permit the use of standard 250-volt exciter generators. Also this arrangement makes it possible to vary the relative shunt excitation of the two mill motors, if necessary, by means of a buck and boost exciter connected across the mid point of the field circuit and a point midway between the two exciters. No occasion has been found to use this latter feature. In addition to the main shunt field winding each motor has a cumulative series field and a differential series field which are cross connected and indirectly excited by series exciter generators. As shown by the diagram, the series exciter generator having its series field in the armature circuit of one double armature motor excites the cumulative field of that motor and the differential field of the other motor. Any tendency of one motor to take more than its share of the load strengthens its field and weakens the field of the other motor, thus quickly re-establishing equilibrium. A similar scheme is used in balancing the loads on the three generators of the motor generator set. The generator excitation is different in that the series fields are excited directly without the use of series exciters, and the current from one generator excites its own differential field and the cumulative field of the adjacent generator.

A valuable feature of this load balancing scheme, as applied to motors, is that any desired speed regulation can be obtained without interfering with the load balancing characteristics. Also, the load balancing effect can be varied without affecting the compounding.

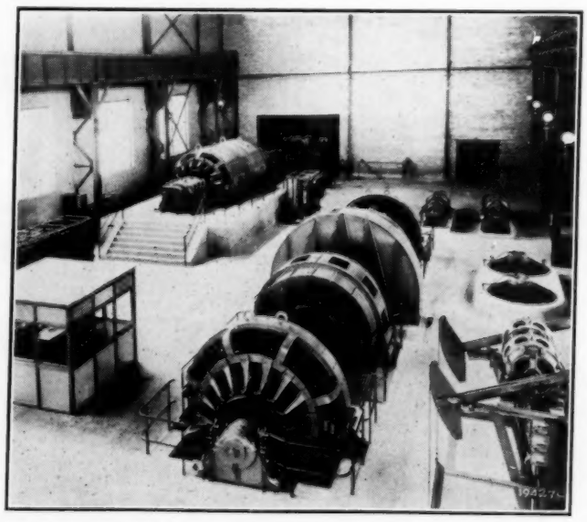


FIG. 4—Photograph of 54" blooming mill twin-motor drive.

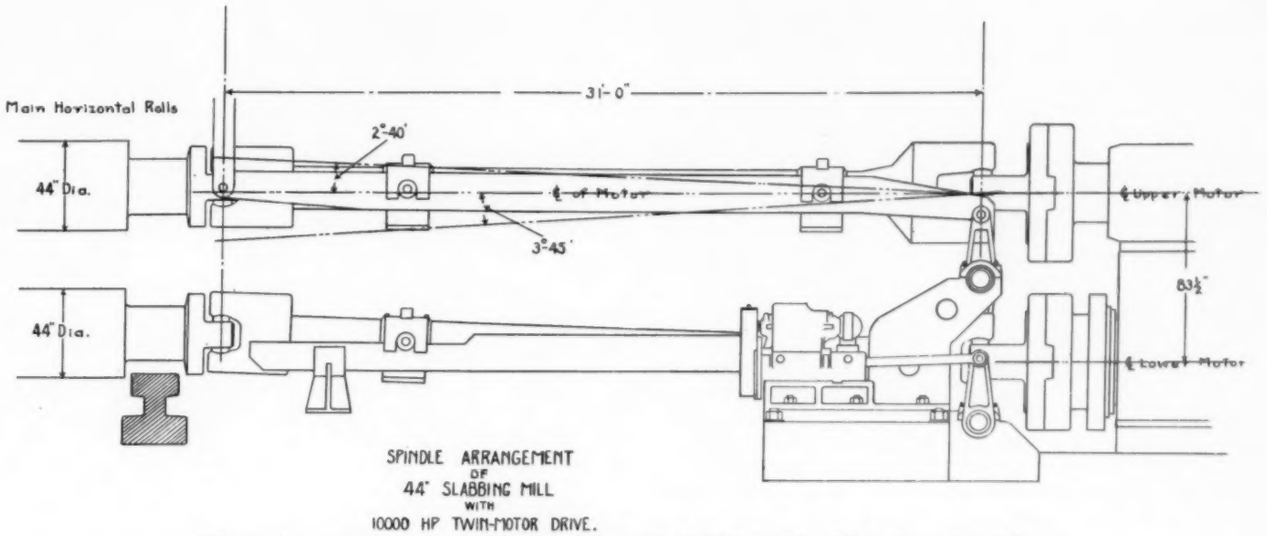


FIG. 5—Arrangement of main spindles for 40" slabbing mill with twin-motor drive.

The mechanical arrangement of the motors, spindles, and rolls is shown in Figure 3. The mill rolls are normally 54" in diameter over the collars and the motors are mounted on 83½" centers. The relative elevations of the motors and rolls are such that the lower spindle operates at an angle of 2½° and the upper spindle has an angle of 4° below horizontal when the rolls are together and 5° above horizontal when the rolls are set for maximum separation. The mill spindles are 25 feet long, which is 4 feet greater than for a duplicate mill with pinions. The maximum angle of the upper spindle for the pinion drive, corresponding to the same roll separation, is 8.5°. Figure 3 shows the comparative space requirements and spindle angles of an 8000 hp., 40 rpm. drive with pinions and a 10,000 hp., 40 rpm. twin-motor drive. It will be noted that with the pinion drive the spindles operate under the most favorable conditions when the rolls are close together. The heaviest loads usually come when the ingot is large and the upper spindle considerably inclined. With twin-motor drive the spindle angle is a minimum when the rolls are considerably separated, which is more nearly the condition for maximum rolling loads.

The motors themselves are mechanically duplicate. The mill end pedestal of each motor is supported on a heavily ribbed cast steel base plate. The sides and front end of the bedplate are fabricated in the usual manner from heavy beams and slabs. The upper motor drives through a jack shaft. An "A" frame on the mill end of the lower motor supports a pedestal bearing which carries the outer end of the jack shaft. The pedestal which supports the jack shaft has no thrust bearing; the thrust being taken on the mill end pedestal of the upper motor. The lower motor has the usual thrust bearing. The motor shafts and jack shaft have forged flanges. The driving halves of the universal couplings next to the motors are bolted to the lower motor shaft and jack shaft in such a way that they can be removed for renewal or repair. The electrical construction of the motor is in line with Westinghouse practice for reversing service.

The operating characteristics of the 10,000 hp. twin-motor drive are quite different from those of a conventional reversing equipment driving through pinions. Probably the first thing which impresses an observer in the mill pulpit is the quietness of the mill. The steel enters the rolls without shock and the usual vibration and noise in the mill spindles is absent. There is practically no tendency for the mill to chatter when the steel is entered in the rolls. On this account the roller does not have to exert the usual care in entering the steel. He can enter on the first trial, even at higher speed, and therefore saves time on the early breakdown passes. With twin-motor drive the phase positions of the rolls can shift independently so that they can quickly adjust themselves to the steel, thus removing the chief cause of roll chatter. On the other hand, with pinion drive the independent movement of the rolls is limited by the back-lash in the pinions and spindles. The lack of real flexibility for independent movement of these parts tends to make the chattering worse rather than to improve it. Next, the observer will note the unusually high rate of acceleration and deceleration of the mill. This is due to the comparatively low inertia of the motors, which allows the control to be designed for unusually fast field response without causing high acceleration currents and high reverse power currents. The electrical equipment is therefore used to better advantage and the capacity for useful work is increased. The rapid response of the motors makes the drive much more easily handled than the usual drive and the steel is kept closer to the mill, with the result that the intervals between passes are reduced. The increased speed of response was quite noticeable to the roller on the 54" blooming mill when the mill was first placed in operation. This roller had previously operated an equipment with a 50% higher base speed, but, due to its comparatively greater inertia and slower fields, the acceleration of the older drive was noticeably slower.

The quick response of the motors increases the entering speed and average rolling speed, thereby decreasing the rolling time and increasing the per-

centage of time that metal is in the rolls. This effect is reflected in the increased power input necessary to keep the flywheel motor generator up to speed. An 8000 hp., 54" mill drive in the Pittsburgh district has a flywheel set with a 5000 hp. driving motor. Satisfactory operation is obtained with a slip regulator setting of 5000 kw. When rolling the same weight ingots with the same number of passes, and with practically the same load currents, in the mill with twin-motor drive, a slip regulator setting of 7500 to 8000 kw. is required to keep the flywheel set up speed, when rolling at a rate which is easily maintained; showing that the rolling is done at a faster rate.

A 44" slabbing mill with twin-motor drive for the main horizontal rolls has also been placed in operation recently. The design of the electrical equipment for the 44" slabbing mill is similar to that of the 54" blooming mill except that the total capacity of the drive is greater. The main horizontal rolls are driven by a 10,000 hp., 40/80 rpm., twin-motor drive similar to that previously described. The vertical rolls are separately driven by a 2500 hp., 79/225 rpm., 700 volt reversing motor. The flywheel motor generator has three 3500 kw, 700 volt generators but is otherwise the same as the blooming mill set. The mechanical arrangement of the main mill spindles is as shown in Figure 5.

The two equipments just described are the first installations of twin-motor drive for heavy duty mills and they have the greatest power which has so far been applied to a single pair of rolls. These two examples will serve to illustrate how the twin-motor principle may be applied to drives for heavily powered reversing mills with roll diameters of 40" and upward. For mills with rolls 40" in diameter and smaller, requiring motor capacity of 8000 hp. and less, the drive can usually be simplified by making each motor with a single armature. The motors can be mounted on smaller centers as the horsepower requirements decrease and the spindle angles can be kept within reasonable limits without the use of excessively long spindles.

It is possible from both the mechanical and electrical standpoints to build a reversing mill drive with one motor on each side of the mill. With this arrangement the diameter of the motor is not an important consideration and the motors can be designed along more conventional lines, whereas, in designing for minimum diameter, the construction may be somewhat special. However, electrical construction details within reasonable limits, are relatively unimportant as compared with other advantages of the twin-motor type of drive and the individual installation should be laid out to fit local conditions.

In recent years the conceptions of steel plant executives and engineers as to the expected output of various sizes and types of reversing mills have become fairly well standardized. Also certain standards have been applied in selecting the electric drives. Where twin-motor drive is to be used, a revision of standards will be necessary. Because of the higher average rolling speed and the reduction in intervals between passes, the capacity of a given mill is increased by a change from the conventional single motor drive to twin-motor drive. Since the electrical equipment is utilized to better advantage in the twin-motor drive, a greater tonnage output with no increase in motor capacity can be expected when this form of drive is used. However, in many cases it will be desirable to provide greater motor capacity in order to take advantage of all the possibilities for increased output.

The principal advantages of the twin-motor drive for reversing service can be summarized as follows:

1. The motor capacity which may be applied to a single pair of rolls is greatly increased.
2. Pinion losses, repairs and maintenance are eliminated.
3. The motors may be designed to have greatly reduced inertia; resulting in less strain on the equipment, more torque available for useful work, reduced motor and generator heating and faster acceleration.
4. Roll chatter and spindle vibration are practically eliminated.
5. Higher rolling speeds can be maintained and mill tonnage can be increased.

The relative first costs of twin-motor reversing drive and pinion drive will vary with the size and torque requirements of the mill. The two motors of a twin-motor drive with the necessary shafting and bearings are more expensive to build than a single motor of equivalent capacity. This increased cost may be somewhat less than the cost of a pinion stand with spare pinions and bearings in the case of a heavy mill and somewhat greater for a light mill. In general, the difference in cost is not great and is a minor consideration as compared to the advantages of twin-motor drive.

Twin-motor drive offers advantages for wide strip mills, both for hot rolling and cold rolling. The chief advantage is that the elimination of the mill pinions does away with the necessity for accurate matching of the mill rolls. In either hot rolling or cold rolling, unless the rolls are very accurately matched, extremely high stresses are set up in the pinions to cause the larger roll to slip and equalize the delivery speeds. With twin-motor drive the motor speeds easily adjust themselves so that each roll has the same surface speed. The problem of load division is quite simple, as wide thin material forms practically a 100% coupling between the rolls.

The simplest form of drive for a strip mill is a direct connected motor on either side of the mill; each motor driving one working roll. This arrangement may be objected to, especially for hot mills, on account of the space taken up by the motor and spindles on the side of the mill which is usually left open. This objection can be overcome by the use of special gearing which will permit the installation of both motors on the same side of the mill. Such an arrangement introduces no new mechanical complications, because it is now customary to use geared motors with pinion drive and the total number of gear units would remain the same. Instead of a reduction unit and a mill pinion unit, each of full capacity, there would be two reduction units each of half the total capacity.

Testing of Lubricants

By FRANK L. GRAY*

In the selection of lubricating oils we depend a great deal upon the integrity of the refiner. Specifications are arrived at, either by the manufacturer of the equipment, through trial, or by the lubricating engineer, who considers the operating conditions of the machine.

A resume of the properties of an oil that are listed in specifications or tested in operation, and how they concern the plant operative will be given here.

Gravity

The gravity of a petroleum oil is an index to the weight. The A.P.I. scale with the modulus 141.5, adopted by the American Petroleum Institute, the U. S. Bureau of Mines and the U. S. Bureau of Standards in December, 1921, is generally in use in the United States today. The relation of this scale to specific gravity is shown by the equation:

$$\text{Degrees A.P.I.} = \frac{141.5}{\text{Specific Gravity}} - 131.5$$

$$\text{Specific Gravity} = \frac{141.5}{\text{A.P.I.} + 131.5}$$

Specific gravity of oil at 60° F. as compared to water at 60° F. as unity.

FRANK L. GRAY

This scale was formerly known as the Baumé scale, but was changed to eliminate confusion existing due to the Baumé scale with a modulus of 140.0, the difference being one-tenth of one degree for heavy fuel oils, up to six-tenths of one degree for gasoline.

Petroleum oils are sold mostly on the volumes corrected to 60° F. It is, therefore, necessary information wherever volume corrections are to be made.

Viscosity

Viscosity is the resistance to fluid shear. The Saybolt universal viscosimeter is almost universally used in the United States, and measures the time in seconds at a given temperature it takes 60 c.c. of the oil to pass through a tube 1.225 centimeters in length and .1765 centimeters in diameter. For lighter oils measurements are made at 100° F. and 130° F., and for heavier oils at 210° F. By the use of the Herschel temperature-viscosity chart it is possible to find the viscosity of the oil at any operating temperature when the viscosity at any two points are known.

For calculating the flow in pipe lines, fluid friction in bearings, or for scientific research, the viscosity is given as a unit of force designated as the poise which is one dyne sec. per sq. c.m. and converted from Saybolt universal viscosity by the empirical formula

$$g\left(.00220\ S - \frac{1.8}{S}\right) = \text{absolute viscosity in poises.}$$

where g = specific gravity
S = time in seconds by Saybolt universal viscosimeter.

Color

A color standard is required to match a given depth of oil by transmitted light. There are twelve standards for oils, ranging from lily white to claret red, and three for cylinder oils. Color generally denotes the amount of refining for new oils and oxidation in used oils. Uniformity may be checked by this method, but too much emphasis should not be placed on this phase, as it tends to higher prices and waste.

Pour Point

The pour point is the lowest temperature at which an oil will pour or flow when chilled, without disturbance. The pour point gives an indication of what may be expected in gravity feed systems, ring oil bearings, or other places of lubrication that are exposed to winter temperatures.

Volatility Point

Volatility is the tendency of an oil to change from a liquid to a vapor, and is denoted by the flash and fire points.

The flash point is the temperature at which an oil emits sufficient vapor to produce a flash from a test flame without igniting the oil while being heated at the rate of 9—11° F. per minute. When the rate of heating is continued, the temperature at which the vapor is ignited and burns for 5 seconds is the fire point.

The first use of the flash point was to indicate the fire hazard, but now it is used for classification and identification. In high operating temperatures an oil with too a low flash will vaporize, and may leave a non-volatile residue, carbon in character, that in time will cause a shut-down.

Water and Sediment

Water and sediment is determined by the centrifuge method, or by distillation for water and extraction for sediment, and is calculated in percent. The precipitation number is the number of cubic

* Lubricating Engr., Gary Works, Illinois Steel Co.

centimeters of precipitate formed when 10 c.c. of lubricating oil are mixed with 90 c.c. of petroleum naphtha and centrifuged.

Neutralization Number

In petroleum products, the presence of organic constituents having acid characteristics, and the contamination by alkalies and mineral acids is denoted by the neutralization number, which is the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. The neutralization number may be converted to percent acidity by the equation

$$\frac{56 \times 1000}{N} = \frac{282 \times 100}{A}$$

Where N = neutralization no.

A = % acidity.

56 = Atomic weight of potassium hydroxide KOH

282 = Atomic weight of acid calculated as oleic $C_{17}\ H_{33}\ COOH$.

1000 = Conversion factor from gram to milligrams

100 = Conversion factor to %

$$\text{Hence: } A = \frac{28200N}{56000} = 0.5\ N.$$

THEREFORE, the percent acidity is practically one-half the neutralization number.

This analysis is of particular value in turbine and other oils used in a circulating system.

Demulsibility

Rapid separation of water is a necessary characteristic, especially in turbine oils. 27 c.c. of oil and 53 c.c. of distilled water are emulsified at 130° F. by rotating a paddle for five minutes at a speed of 1500 R.P.M. The rate of settling out of the oil in c.c. per hour is called the Herschel demulsibility.

The rate of separation is decreased or possibly prevented by foreign materials. This is a physical condition known as an emulsion.

Oils in service, i.e. in circulating systems, bath lubrication, and even new oils in storage must be tested at intervals for oxidation, moisture, sediment, or other changes in its properties.

Several analyses are given here to show action of oil over a period of time while in service.

Turbine Oil, 140/145 Viscosity @ 100° F.

Hours in Service	Neutralization Number mg. KOH Per gr. of Oil	Acidity in %	Demulsibility	Color
New	.01	.005	1620	water white
594	.01	.005	1500	1—1½
2602	.01	.005	600	1
5373	.02	.010	1020	1
8337	.04	.020	570	1½
12431	.029	.0146	780	1—1½
14865	.023	.0116	1200	1—1½

This oil is operating in a 30,000 KW. Turbine at 1500 R.P.M., with bearing temperatures of 110-120° F. 2,000 gal. of oil are in the circulating system, which has a by-pass continuous filter. 150 gals. of make-up oil per year are used, and the oil is centrifuged about every 18 months.

Turbine oils deteriorate in service, due to oxidation. Asphaltic material insoluble in the oil, or soluble free acids are products of oxidation. In the presence of water free acids form insoluble soaps when in contact with iron or copper. These are the properties of this class of oils that we are most interested in. When the acids form soaps they become powerful emulsifying agents, and when water is present, an emulsion is formed. The stability of this emulsion depends upon the extent of the acid soaps present. It is for this reason that a close check is kept on the acidity and demulsibility of the oil in service. As the acidity gets higher the separation becomes worse, so we have set a figure of .75 mg. KOH/gm. of oil as the point at which this oil must be changed. Asphaltic material, another cause of oxidation, will be detected by the color test and also by the precipitation number.

Emulsion tests on new turbine oil will determine the initial quality of the oil and the care of the refiner, but have no bearing upon the stability of the oil in service.

Twenty-seven samples of oil were taken over a period of five years from a continuous filter with auxiliary heating and settling tanks of a three cylinder direct connected 4000 HP. reversing steam engine and a twin tandem geared 10,000 HP. reversing steam engine. The oil is constantly subject to contamination by steel mill dust and 5% compounded cylinder oil. 3,500 gal. are in the system operating at 430 gal. per hour, and an average of 500 gal. per month are added as make up. The oil used is a treated, neutralized and filtered light engine oil with a viscosity of 125/135 sec. Saybolt at 100° F.

	Viscosity at 100° F.	Moisture %	Sediment %	Neutralization Number mg. KOH/gr. of Oil
(New Oil)	132	None	None	.06
	* 250	.48	.63	.60
	263	* .22	* .04	1.37
	343	.44	.29	* .58
	380	.96	** .96	1.43
	400	** 2.16	.43	** 1.79
	** 440	1.96	.26	1.49

* Minimum — ** Maximum

A direct relation is shown between viscosity, moisture and acidity, but not so with sediment. The sediment present in the samples is a fine mill dust soluble in the oil at high temperatures, which has an indirect bearing on the viscosity of the oil and a direct relation to the sludge formed.

With the same system working on less capacity, operating at 780 gal. per hour, a sediment percentage of .49 was recorded after the settling tanks has been cleaned and 700 gals. of make-up oil added. Two weeks later at a rate of 720 gal. per hour the sediment had increased to 1.34%. During this period an average of 1692 gals. of make-up oil per month was added. The great amount of make-up oil was necessitated by the rapid formation of an emulsified sludge, due to the fact that the oil did not have sufficient rest to settle out the suspended solids.

By periodical analysis only can oils in service be intelligently watched and unnecessary shutdowns prevented. This necessitates the co-operation of an oil chemist or one competent to use the proper equipment for an oil analysis.

In the evaluation of greases, we must depend more on the mill tests than upon the laboratory. A grease is received for the particular work it is to perform and has certain general characteristics, such as melting point, penetration, consistency, base, fillers, % and viscosity of the oil.

The melting point denotes the heat resisting properties, and in a general way the quantity of soap present.

Consistency is dependent upon the soap content.

The penetration test, which measures the depth in tenths of a millimeter, a cone weighing 102.5 grams will penetrate the sample in 5 seconds at 77° F., is generally used as a gage for the consistency of a grease. The sample is specified as unworked for a grease whose structure has not been disturbed, and worked, where a plunger or a spatula has been used to thoroughly work the grease.

Having found by mill test the correct penetration of a grease, tests may be made to insure uniformity in future shipments. However, two greases of the same penetration may behave differently in service due to a different composition.

Greases are usually classified as to the basic constituent. A base of calcium soap forms an emulsion of water in oil and is insoluble in water. Sodium soap forms an emulsion of oil in water, and is soluble in water. Specialty greases will have as a base petrolatum, lead, aluminum, etc.

Fillers, such as graphite, talc, mica and asbestos have definite values for particular uses in a lubricant. A filler may be added as a cushioning power to reduce noise, as a seal, as adulterants, or, in the case of a high grade amorphous or flake graphite, for its lubricating qualities. A lubricant containing a filler is usually manufactured for a definite practice and should be considered in the application of this class of grease.

As the viscosity of an oil is considered in an oil lubricated bearing, so is the viscosity and percentage of the oil considered which is contained in a grease.

Properties of a grease are mostly physical in character. The ability of a grease to form a film and reduce friction are without the sphere of chemical analysis. For this reason the mill test is always the final consideration.

All tests should have as their primary object, better lubrication without waste, at a lower cost. It follows that a piece of machinery better lubricated will have reduced friction and wear, shutdowns and delays will be prevented, and, although more grease or oil may be used at a higher price per pound, the saving in time and equipment will greatly offset the increased cost per ton of product for lubricants used.

The methods of test are varied and usually up to the individual. A few examples of mill tests follow:

Billet Mill Roll Necks: Block vs. Tallow Neck Grease

Test	Steel Rolled Tons	Power KW. Hrs.	Grease Pounds
Block	1,000	11973.5	51.12
Tallow Neck Grease	1,000	11804.5	64.79

The object of the test was to furnish better lubrication.

Gear Shields as a Protection for Open Table Gears

	Test No. 1	Test No. 2
Tons	394,110	398,860
Days	61	61
Gears changed		
Feed and runout tables	45	20
Line shaft and table roller	88	27
Savings in cost gears and mech. labor		$2,735.22
Increase cost of lubricants		693.89
Net saving		$2,041.33

Tar vs. Greases for Hot Rail Mill Skids

Gallons tar per ton steel	.04150
Pounds grease per ton steel	.01690
Cost tar per ton steel	$.00178
Cost grease per ton steel	$.00084
Tons steel per gal. tar	24.1
Tons steel per lb. grease	59.2

1 lb. grease = 2.46 gal. tar, quantity basis.
1 lb. grease = 2.12 gal. tar, cost basis.

In addition to the saving, the grease eliminated the accumulation of tar beneath the hot bed, which was the object of the test.

Two comparative tallow neck greases were tried on an 18" Merchant Mill, with the object of comparing the grease consumption.

	Test No. 1	Test No. 2
Pounds Grease	350	368
Cost per pound	$ .065	$ .061
Cost	$22.75	$22.45
Production—tons	4071	3272
Cost per ton	$.0056	$.0069

With the advent of the pressure systems into the steel industry, the consistency of the greases is being reduced and in return a more efficient lubrication is received. For, after all, a grease is no better than the oil it contains, and only by continued tests can we hope to convert unnecessary friction to useful work.

Conductors of Heavy Alternating Currents

By D. I. BOHN* and H. W. PABST†

Increasing attention is of late being given to the design of heavy alternating current conductors in steel mills. Loads have in many cases reached a point where re-enforcement of conductors alone will not provide the desired extra capacity. It is desirable to limit the conductor temperature rise to 30° C., largely to assist in maintaining reasonable temperatures of connected equipment.

Direct current conductors have not been a great problem, as the usual practice has been to determine the quantity of conductor material on a basis of a fixed current density, which for the usual flat bar, laminated design, results in an efficient reliable installation.

With the adoption of alternating current equipment, heavy current conductors became very much more of a problem. A single conductor made up of any number of laminations is definitely limited in capacity if safe temperatures are not to be exceeded, and, as an example, it is definitely known that six or even more 4x¼ copper bars spaced ¼ inch apart, with faces vertical, will not carry over 3000 amperes at 60 cycles and stay within rated temperature rise.

"Skin effect" and "proximity effect," the common terms to designate the characteristic of alternating current conductors which distorts the reactance of individual laminations of a single conductor so that one lamination carries materially more current than others, may be readily illustrated by a simple sketch

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(Fig. 1) for ten bars in parallel, each ⅛x3 inches and spaced ⅜ inch apart. We may also illustrate the flux linkages about this conductor as a group of concentric circles about the center point of the group of conductors. Obviously any conductor material near this center point has the greater number of flux linkages and consequently the highest reactance so that these points will carry less current than points farther away from the center in order to have the same voltage drop over a given length of bus. Proximity effect, of course, is a distortion due to the magnetic effect of one conductor on another and actually need not be considered if ample space is provided between conductors, or phases if we are considering a three phase system.

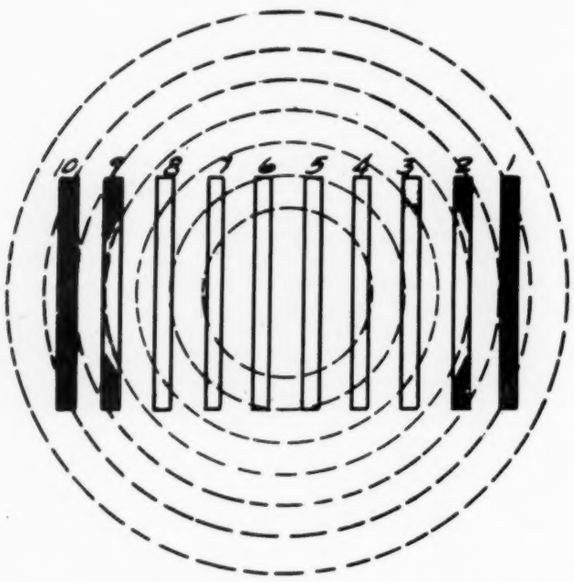

FIG. 1—Laminated bus of 10 3x⅛-inch bars ⅜-inch apart with concentric circles indicating magnetic flux linkages.

The current in such a bus as illustrated in Fig. 1 has been measured and likewise the current in each individual bar of the bus. The current of the individual bars was plotted with reference to the total current and the vector illustration is given in Fig. 2 which shows an arithmetic total current for the bus of 4849 amperes, whereas the net or resultant line current was only 4380 amperes. The difference, usually spoken of as circulating currents, only provides unnecessary heating. The bars at the center of the group could very well be omitted without changing the net capacity of the bus.

From the skin effect standpoint tubular conductors have been thought of as ideal, but it must be remembered that a tube does not provide as great a heat dissipating surface as a laminated conductor for the same amount of material, and consequently a laminated bus may be designed to carry more current for a given temperature rise than a tubular bus.

It has been proven mathmetically and verified by test that for a 60 cycle frequency and definite outside diameter a tubular conductor may carry more current than a solid rod of the same electrical conductivity material and same outside diameters. For the larger size tubing there is a maximum wall thickness beyond which any increase is not accompanied by an increase in current capacity. This is illustrated in the curves of Fig. 3. Standard iron pipe size tubes are usually used. Their maximum recommended ratings are shown in Table I.

TABLE I.
PIPE SIZE TUBULAR CONDUCTORS
CAPACITIES FOR 30° C. RISE AT 60 CYCLES
Based on 30° Ambient

	PIPE		COPPER		ALUMINUM	
Size	O. D.	Area	Weight per Ft.	Amp.	Weight per Ft.	Amp.
½	.840	.250	.965#	450	.292	350
¾	1.050	.331	1.278	570	.399	440
1	1.315	.494	1.906	740	.578	570
1¼	1.660	.675	2.605	940	.79	730
1½	1.900	.80	3.085	1075	.936	830
2	2.375	1.08	4.17	1360	1.263	1060
2½	2.875	1.71	6.6	1840	2.0	1430
3	3.500	2.21	8.53	2230	2.58	1730
3½	4.00	2.68	10.35	2540	3.14	1980
4	4.500	3.18	12.28	2880	3.72	2230

Obviously flat bar can be arranged to partially offset skin effect influences and secure higher capacity per unit of conductor material than in such an arrangement as given in Fig. 1. The "modified hollow square" bus design, so called because flat bar is arranged so that the groups of bars approximate a square in arrangement, although all major surfaces are kept vertical for best heat dissipation by convection, has relatively high capacity. Current ratings for various arrangements of the modified hollow square bus design are given in the curves of Fig. 4.

The desirable mechanical and electrical features of both bars and tubes have recently been combined

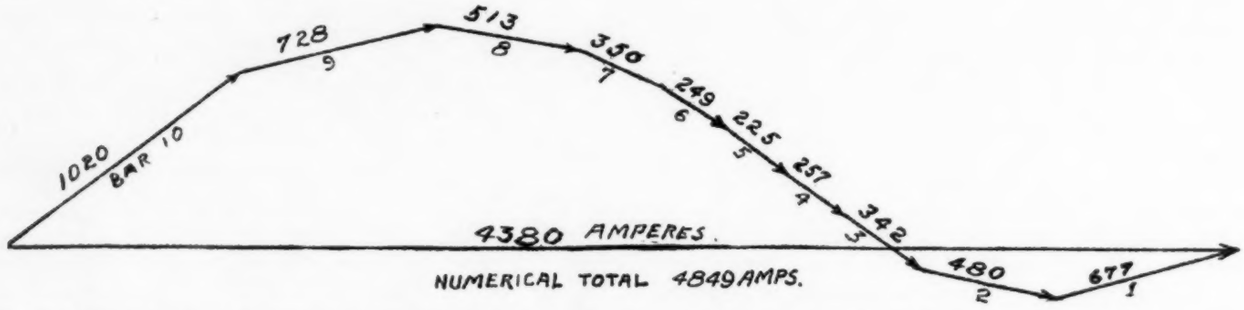

FIG. 2—Vector relation and value of currents in individual laminations of bus, Fig. 1. Difference in current between bar 1 and bar 2 caused by influence of return phase adjacent to No. 1 bar side distorting magnetic field of the 10 bar bus.

in a conductor design consisting of two aluminum channels arranged to form a split hollow square. Tests showed a very low skin effect ratio, being

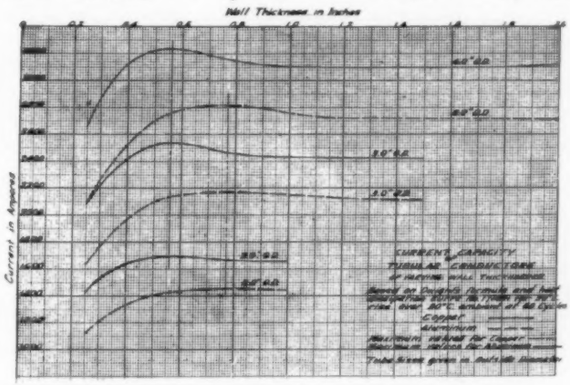

FIG. 3—Variation in current capacity of tubular conductors for constant outside diameters and varying wall thickness.

comparable to a tube in this respect. Table II gives ratings of various sizes of channels arranged in this manner.

TABLE II.
CHANNEL CONDUCTOR RATINGS

For pairs of aluminum channels arranged to form a square. Temperature rise 30° C. over a 40° C. ambient, at 60 cycles.

Size of Channel	Web Thickness	Flange Width	Lb. per Ft. (2 channels)	Cross Section (2 channels)	Effective Current Density	Rated Amperes
4	.180	1.580	3.80	3.14	796	2500
4	.247	1.647	4.44	3.68	762	2800
5	.325	1.885	6.40	5.28	683	3600
6	.437	2.157	9.26	7.64	615	4700
7	.524	2.404	12.26	10.14	563	5800
8	.579	2.619	15.12	12.50	536	6700

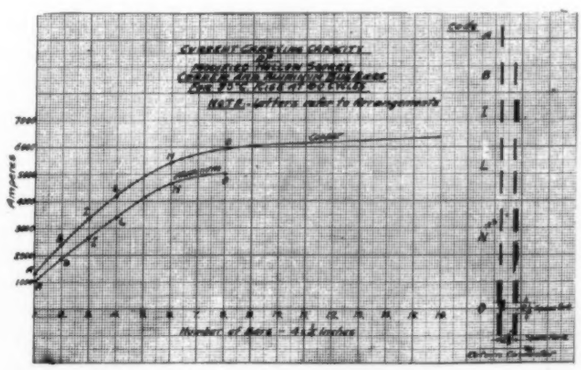

FIG. 4—Current carrying capacity of 4x¼ bar conductors arranged in modified hollow square for 35° C. hot spot rise. Return conductor spaced 18 inches or over.

Expansion problems have never been very serious with flat bar construction as the flexibility of the bars themselves took care of it adequately in most cases. The extreme rigidity of the channels as compared with the bars indicated that definite provision should be made for expansion.

Fig. 5 shows the type of bus support which was developed to take care of this feature. This support is so designed that the channels are free to move longitudinally, a small clearance being provided between the channels and the support member. When it is desired to provide a rigid support a washer may be left out of the support assembly, and a tightening of the main clamping screw will rigidly clamp the channels.

In a great many cases, particularly where extremely severe shortcircuit currents are not involved, spans of 15 to 25 feet between supports may be

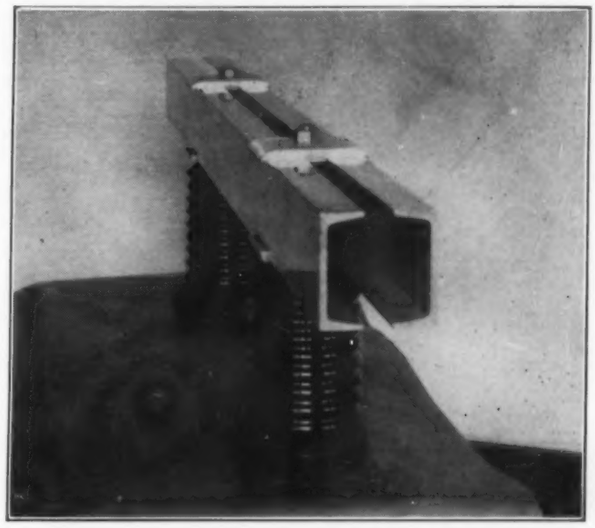

FIG. 5—Channel bus mounted on 25 K.V. insulator. Section close-up.

used. Where the phases are arranged vertically with respect to each other the great rigidity of the channels in this direction will in most cases permit these long spans, even where heavy shortcircuit currents may occur. Where the phases are arranged horizontally the channels may be fastened together at points in the span to provide in effect a truss. This may be done either by bolting a small plate

FIG. 6—Low voltage 5000 ampere installation at Alcoa.

to the flanges, or by using a bus support without the insulator.

All splices and angles are made by using an internal bolted splice plate. The channels are mitered in the case of an angle to properly fit together and to present a neat appearance, and the internal splice

plate, of whatever shape is required and having a section approximately equal to the channel, is inserted internally and bolted as shown in Fig. 7. No difficulty is experienced in the field in connecting splices and angles as ample space is provided between the channels to permit the nuts to be held in position.

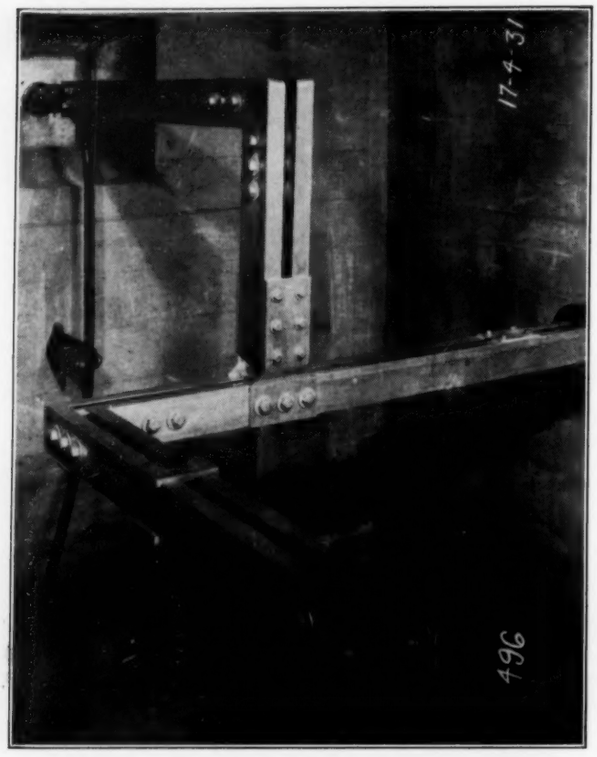

FIG. 7—Chute a Caron power house installation, channel bus for 13.2 K.V. amperes.

In general, taps to the channel type of bus are made with flat bar suitable for connecting to the terminals of the equipment. These bars are bolted to the channel the same as would be done with normal bar construction.

Fig. 6 shows the end view of a 6000 ampere, 440 volt, 60 cycle bus used for supplying electric heating load in a new plate mill located in Alcoa, Tennessee. Two circuits were used in order to reduce the reactance.

For this low voltage work a somewhat different type of support is used. Insulated pipe supports are used to hold the channel clamps, and the details of the support are such as will permit longitudinal expansion of the channels.

Except in extremely long runs no expansion joints will be necessary, and if desired one set of supports near the middle of a bus may be clamped rigidly to the channels, permitting expansion in both directions.

The Chute a Caron power house, located on the Saguenay River in the Province of Quebec, will contain four 56,250 K.V.A., 13,200 volt, 60 cycle generators, two of which are in service at present. Channels are used for the main bus connecting the generator, oil circuit breaker, and transformers.

Fig. 7 indicates the junction of the channels used for low tension transformer delta and the main lead from the oil switch. Conventional porcelain tubes are used through the wall, except that the hole is made square.

The Practical Side of Metallurgical Heat Application

By H. DOBRIN*

Metallurgical heating has taken a very important rank in recent years as an integral part of the operation of a steel works. The function of heat engineering up to a comparatively short time ago had been carried out by the steam engineering department. The steam engineer has performed a great work, as is evidenced by the large number of efficient boiler plants, and also the generally improved methods of utilizing blast furnace gas. The general efficiencies have been raised to such an extent that in a modern boiler plant today 80% efficiencies are expected, and there are some plants that have attained efficiencies as high as 83%. Some of these power plants are equipped with the most modern devices that the mechanical art has developed.

In contrast to these high efficiencies of the boiler plant, general efficiencies in metallurgical heating hardly average 20% for most reheating processes. This is not merely a surmise. In the sheet and tin mill industries the general efficiencies hardly reach 18%. These figures do not attempt to cover recent modern installations, but they approximate the general state of modernity to be found in the average works, a state which leaves quite a rich field for improving efficiencies in metallurgical heating if results in the power plant are to be approached. We find, for instance, that in a modern boiler plant flue gas temperatures of 600° F. and below are generally recovered into some additional preheated air. Large sums of money are being expended to extract the last few per cent of boiler efficiencies until we run sharply up against the "law of diminishing returns." On the other hand, in metallurgical heating flue gas temperatures of 1600° to 1800° F. are treated with indifference, and only here and there are organiza-

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tions sufficiently alert to harness and utilize this costly waste heat.

In an attempt to cope with some of this wastage, there has recently grown out of the steam engineering department a supplementary function, namely, that of the metallurgical combustion engineer. In some forward-looking and progressive organizations these two functions have been entirely separated, even to the extent that the metallurgical combustion function has been encouraged by larger expenditures on the part of managements, in an organized effort to recover this large wastage. The problem in the boiler plant is of only one kind—conversion of water into steam—and it varies only in degree—10 H.P. or 1000 H.P., 100# pressure or 1000# pressure. In metallurgical heating the problems are more complicated.

H. DOBRIN

There was a definite reason why metallurgical combustion had been neglected in favor of the steam engineering function. In steam engineering, fuel economy, pure and simple, has been the ruling consideration. In metallurgical heating, quality, yield, grain structure and surface have been the ruling considerations, and fuel economy merely a side issue. Those engaged in metallurgical heat treatment know but too well that many a product has resulted in a second instead of a prime due to over-anxiety for saving fuel.

However, as the metallurgical combustion engineer has learned his art of properly applying fuel with quality as the prime consideration, the incidental benefits of fuel economy have also generally resulted. It is as easy to spoil the quality of a product by the application of too much fuel as by the application of insufficient fuel.

For some years there had been hardly any departure from the traditional open hearth regenerative Siemens type furnace, but in recent years many improvements have been brought about and there have been some types developed which have been almost a complete departure from the old reversible furnace. The fundamental requirement of determining the exact ratio of the fuel and air necessary for combustion had been totally neglected, but today the standard usage is to provide combustion control for the proper ratios of fuel and air. One finds even such refined developments as the automatic reversing of furnaces by the predetermined temperature of the checkers on each side of the furnace; pressure fans for the delivery of the necessary air; induced draft fans for drawing the products of combustion out of the furnace; the insulation of checkers and also the complete steel encasing of such checkers are now to be found on some of the latest open hearth furnaces. Automatic stack damper control and the introduction of multi-pass checkers are also being attempted here and there. There have been quite a number of successful organizations sponsoring instruments and controls for the manipulation and operation of these furnaces. These sales elements have constituted an influence for great good and have become a useful handmaiden to the work of the metallurgical combustion engineer. In some cases they have been able to reach the ears of managements and have been able to put their story across more successfully than the average combustion engineer who is resident in the steel works.

In the soaking pits, also, there have been changes. Here again the traditional type of soaking pit which has been employed since the inception of the industry, has made great advances. Here, too, we find more attention being paid to the control of the air and fuel necessary for combustion, insulation of checkers, pressure fans for the determination of the proper amount of air, as well as an induced draft means for the removal of the spent gases out of the furnace.

There have been a number of successful new types of pits which are today considered standard units. The first of the new type pit, which only ten years ago was in its experimental stage, is the direct-fired pit. This pit represented a complete departure from the traditional type, in that it did away with the reversing of the furnace, did away with the checkers, and did away with the old method of indiscriminately pouring in as much fuel or air as would appear possible in the judgment of the heater. Formerly no attempt was made to determine the amount of gas and air needed to produce the proper temperatures and uniformly and properly to heat the ingot in the soaking pit. This heating was usually attended by a heavy jacket of scale, which, to the old heater, seemed almost a necessity. In fact, in the very plant where this direct-fired, non-reversible, controlled ratio of air and gas pit was introduced, it was very difficult to overcome the traditional requirement of a heavy jacket of scale around the ingot. The blooming mill organization was dissatisfied with the appearance of the ingots. The ingots that were withdrawn from this experimental pit were uniformly heated both top and butt; they rolled to the satisfaction of the mill organization; it was possible to reduce them to the required section in fewer passes; they were soft down to the core; but still the heaters were dissatisfied. The refrain was: "There must be a jacket of at least ½ to ¾ of an inch of scale, because that is the only proof that it has been thoroughly soaked through." All kinds of interference had to be dealt with, and sometimes (in the mornings) the ingots of one side of the pit would be burned up. In order to discover the causes for burning up these ingots a flow meter

was set up. Naturally it is characteristic of this type of instrument that each time the furnace would be reversed a definite record of such reversal would be shown on the chart. You can imagine the amazement when the next morning we found that the pit had not been reversed at all for six or seven hours. This flow meter had been installed during the day time and put in an inconspicuous location, so that the heater who was on night turn naturally did not know about this instrument. But when confronted in the presence of the manager with this indisputable telltale chart, he then and there confessed that he did not like this new idea and did not think much of it. Later this heater became one of the most ardent enthusiasts, and helped to make this type of pit a success. In this same organization all the soaking pits are now of the direct-fired, non-reversible, checkerless type.

There have been other types of good soaking pits recently introduced where there is proper temperature and combustion control, insulated checkers and proper stack damper control, and means for inducing draft out of the pits into the stack. There are also the one way, recuperative, non-reversible pits, which give satisfaction to many. All this, of course, required much development on the part of the metallurgical combustion engineer.

Starting from the ingot, the ramifications assume manifold proportions. After the ingot has been reduced to a slab, billet or some other shape, the ability of the metallurgical combustion engineer is put to a severe test. What is going to be the ultimate product of this ingot? Is it going to be a sheet? If a sheet, what kind of a sheet—black, or galvanized and corrugated, or blue annealed? Is it going to be a high grade, full-finished sheet for automobile use, or is it going to be used for an enameled range or furniture? If it be a flat metal, is it going to be a sheet bar or a tin bar? Are the slabs going to be rolled into plate, or is the billet resulting from the ingot going to be fabricated into a spike, rivet, wire or nail, rail, tie plate or splice bar. Then again, what kind of fuel will be most suitable for any of these applications. Depending on whether oil, by-product gas, natural gas, producer gas, mixed gas, tar or coal be the available fuel, the furnace design may have to vary in each case.

Any one familiar with the diversifications to which all this leads will readily see the great number of heat applications that must be kept in mind, and that each and every one of the heat applications through to the finished product will have a very important bearing upon the type and kind of product, its saleability and also its general value.

Assuming that the steel was of the proper analysis and of required specification, the question of whether a sheet will be a prime or a second has greatly to do with the application of heat. It is true that many other factors enter into this question, and there may be causes other than the wrong heat application to affect quality, nevertheless, let us assume that all the factors other than the heat application have been properly taken care of. Suppose the steel is rolled into skelp for welded tubing, or into a round for a seamless tube. The skelp, if of large size, has to be heated to a certain temperature in one furnace, then transmitted to another furnace. Here the real problem and the real worry begins, as improper heating will produce imperfectly welded pipe, with surface imperfections sufficient to result in a rejected or second grade product.

If the steel is to be converted into seamless tube, the bloom has to be turned into a round solid billet. Those engaged in the manufacture of this product know only too well the rolling difficulties encountered when such a large mass of steel, say 12 x 12", or 14 x 14", has not been properly and uniformly heated.

Granting that it has been properly and uniformly heated and has resulted in a well rolled round, it again has to be reheated for piercing, and here again is an entirely new problem. Those engaged in this art know that it is of great importance that the inside of this round billet or the core be perfectly heated, since the place of attack, from the standpoint of the mechanics of piercing, begins at the center of this round billet. Heating the outside surface, no matter how well, will not result in good piercing. The problem here is, how is this steel going to be heated so as to be hotter in the middle than on the outside. This is a problem to tax the ingenuity of many a metallurgical combustion engineer. Of course, means have been found to effect such a desired type of heating. This has been done by the introduction of a multi-zone furnace, where the steel is properly heated to the desired temperature of the inside of the billet some distance before it is discharged into the mill. Afterward it passes into a soaking zone which is at a somewhat lower temperature, thus preserving the temperature on the inside of the billet and, in a measure, conditioning the temperature of the steel on the outside of it. This type of application, coupled with proper temperature and combustion control, has come into vogue in recent years.

At this stage, the tube, if it has not been originally fabricated to its proper gauge and size, has to be reheated and taken through a reducing furnace —a new problem again. Here it is a question of gauge and surface, and there must be accurate control of the furnace gas atmosphere. It is not well to overheat this steel, nor is it well to have too much difference in temperature between the front and the rear end of this pipe. On account of improper heating at this particular stage, many rejections may result.

The practice from here on for some kinds of pipe is that it has to be upset. The purpose of upsetting is that the end of the pipe used for threading be of a heavier section than the rest of the length of the pipe. This additional heating process requires an upsetting furnace, which is an open furnace deep enough to hold some two feet or 18 inches of the end of the pipe. The rest of the pipe is out in the open and is not heated. It is of great importance that this pipe be not heated so as to sweat, nor heated so that it will result in excessive scale, as the end of this pipe is inserted into a press, which constitutes a drop forging operation. Furnaces of this kind, if not properly designed, usually have a very short life, and in some plants the necessity of continually rebuilding them constitutes a real problem.

Some of this pipe may have to be normalized. Here again is a very delicate heating operation which must meet the metallurgical requirements. This

means proper grain structure, ductility, smooth surface and proper tensile strength. Depending on the kind and type of steel and the physical properties required after normalizing, the metallurgy of this process may require a temperature of 1600° F. or it may require a temperature of only 1150°. These are problems indeed, in view of the fact that the size of the pipe may vary anywhere from 4 inches up to 13 inches in diameter. Considering the mass that has to be heated within such a furnace and the fact that there must be great flexibility in the input of the amount of fuel, this type of furnace, to be successful, requires a great deal of ingenuity.

It must be remembered at this point that for all proper metallurgical heating it is of the utmost importance that the furnace pressure be positive and not minus. In other words, there must be no permission for undesired air to enter the furnace other than the air that has been ordered to be admitted with the fuel to be burned. If, for instance, the size of the pipe be 13 inches, so much more fuel is required to heat such tonnage from cold say to 1550°. In such a case it is comparatively simple to fill the furnace full of non-oxidizing gases and have a definitely positive pressure within the furnace. However, when the requirement is to heat perhaps only 4" pipe to 1150° F., it is very difficult to fill the furnace with the required flue gas volume. The problem here is intensified because there must be a certain cubical volume to heat a certain amount of steel to a certain temperature. It is therefore necessary not only to have the ideal volumetric condition for a heavy demand, but still to have this furnace volume serve effectively at the very much lower requirement. It may be of interest to mention that in one particular case where such a furnace meets all these requirements, there are a multitude of zones of special control, and a very large upturn and an extremely low downturn. The burners are very flexible. It is possible to burn one fuel volume and increase that to eight fuel volumes. At the same time, the proportions and ratios between gas and air are not disturbed, and the characteristics of the mixture and its non-oxidizing quality is maintained at its highest maximum and also at its lowest minimum. There is also a stack damper control incorporated in the combustion scheme of this furnace.

It is intended to bring out here that in following through the various heating processes required to manufacture say a seamless tube, quite a variety of furnaces have to be employed in order to produce a satisfactory product and at the same time meet required production costs. Any one of these furnaces in the chain of the process may undo the good of all the rest of the furnaces. Here the chain is not any stronger than its weakest link.

Going now into the phase of work involved in the manufacture of a high grade, full finished sheet, the problems get more and more complicated.

In recent years the sheet mill industry has undergone a very important fundamental change. The problems were manifold even at the time when the bulk of sheets were produced from the pair into the pack, and the pack reheated and rolled into sheets, then box annealed and finished. But with the continuous process of rolling sheet metal from the ingot into a slab, and from the slab into breakdowns, and from breakdowns finished through continuous sheet rolling and continuous normalizing, the heat applications have required more rigid attention. So complicated has this problem become that very often one seeks for the cause of trouble at the point where it is immediately apparent, while it sometimes turns out that the seat of the trouble is, perhaps, two or three processes further back.

Even with the old method of rolling from the pair into packs and then finishing, it had become the almost subconscious habit of the operating organization to employ a non-oxidizing or reducing furnace atmosphere so as to avoid the kind and type of scale which results from the admission of free air which had not been previously mixed with the fuel, and in a number of plants it was the common practice to burn the fuel in the furnace with every opening for the admission of air not only closed off, but sealed up with wet clay. If one is observing, this will be found still to be the case in many plants. This is not only confined to sheet or tin mills, but can be noticed in other mills. The only air that can possibly come into the furnace is that which the stack can pull in through the door openings. Naturally, such a method of combustion is bound to result in the issuance of black smoke out of the stacks and the consequent waste of fuel. Strange to say, even with these precautions, the elimination of scale has not always been achieved. Such applications have been attempted mostly with solid coal and producer gas, and occasionally even with the use of by-product gas. The result usually is that the fuel does not really begin to burn up until it has already left the furnace where it can meet with some air due to the infiltration of such air in the outgoing flue, caused by the suction of the stack. So the practice prevailing and dictated mainly by instinct has been that there must be no air admitted into the furnace. This has always been called a reducing atmosphere.

For the sake of clarification let us repeat a well known fact: by a reducing atmosphere is meant an atmosphere under which the fuel is being burned with a shortage of the necessary air. In the same way an oxidizing atmosphere means that the fuel is being burned not with a shortage but with an excess of oxygen.

In a plant where this feature of carrying a highly reducing atmosphere was known to be of great importance and where every means was apparently used so that such an atmosphere be consistently carried, a superficial examination of the gases in the upper half of the furnace and immediately over the top surface of the packs showed what may be called a reducing atmosphere. Since the degree of an atmosphere is mainly judged by the content of the unburned CO or carbon monoxide, the analysis showed, in this particular case, 3.9% of CO and 10% CO_2. Without a complete analysis of all the gases, no one would have questioned that this was a reducing atmosphere, but upon a complete analysis of the gases this was found not to be the case. This furnace was arranged with the burners on each side, the packs going through on shafts. There was also a chamber underneath the shafts which had been equipped with burners.

In a further process it was discovered that many of the sheets had scratches and pits, and that this invariably occurred on the sheets that had been lying on the top of the shafts. This furnace was

equipped with seven shafts, and a flue gas analysis was taken under each one of those shafts. Here is the kind of reducing atmosphere that was found there:

BOTTOM BURNERS ON

Shaft	CO_2	O_2	CO
#1	10.0	1.0	3.9
#2	9.8	1.4	3.2
#3	8.8	2.5	2.7
#4	10.2	2.2	2.6
#5	8.0	4.6	1.6
#6	8.4	4.6	1.2
#7	7.2	7.2	0.4

This was the analysis of the gases with the bottom burners on, with a content of free oxygen anywhere from 1% to as high as 7.2%. With the bottom burners off a condition was found which was quite a revelation. Since it was important to have a reducing atmosphere here, imagine the surprise of finding such an analysis as this:

BOTTOM BURNERS OFF

Shaft	CO_2	O_2	CO
#1	4.2	13.0	0.0
#2	9.4	5.0	0.0
#7	7.6	6.4	0.0

The insertion of a testing tube under the shafts disclosed that there was no reducing atmosphere in this furnace at all. No wonder there were scratches and pits.

The mistake made by many engaged in this work is that they are too prone to judge a reducing atmosphere by sight, or to name an atmosphere as reducing merely by the content of the unburned carbon monoxide. The element, and an important one, which has to be reckoned with is not the extent of the reducing quantity, but **stratification.** In some cases there may have been a shortage of total air admitted with the burner into the fuel, but if the air has been permitted to run into the furnace unit stratified and unmixed, it will invariably damage the material before it has had a chance to mix with the combustibles in the fuel. The degree of damage varies with the temperature within the furnace. At a temperature below 1300° F. the effect will not be as destructive as it is with mounting temperatures. Approaching 2000° F. it gets to be of a very voracious nature. The metallurgical side is that certain oxides are formed which adhere closely to the surface of the steel. In the pickling process an attempt is made to loosen and remove all these oxides. Some oxides which were caused by the chemical reactions which occurred from the liberation of the H_2O or water vapor, which always is a product of combustion, will not as adversely affect the surface of the work; but the free oxygen, and not the oxygen which resulted from the breaking down of the H_2O during the process of combustion is the destructive agent. This has something to do with the intricacies of the chemical behavior of gases, and, of course, is outside the scope of this paper.

The causes for scratches and pits in the particular instance mentioned above were noticed at the end of the pickling process, and since they passed through the normalizing furnaces before entering into the pickling baths, the cause was sought in the furnaces immediately preceding the process where these defects were noticed. Two types of furnaces were being employed here for normalizing. One was an old application which was thought rather obsolete, and the other was a more or less modern application. The investigation resolved itself into trying to find the cause in the more or less obsolete furnaces, but these defects also showed up at the end of the cycle coming from the modern furnaces. So, in this particular case, the trouble did not disappear until it was discovered that the pack heating furnaces produced a kind of scale or oxide which resulted in these defects.

In this particular connection it will also be well to mention that burners may be very deceptive even though they look very similar. They may have the same appearance but they do not function in the same way. In one particular plant a certain type of burner which was supposed to be of an automatic proportioning type could not be made to produce the kind of a mixture which would result in non-scaling of the product. A burner which looked very similar to this unsuccessful burner, as soon as it was installed, corrected practically all this trouble. When this deceptive burner was sawed into halves and when the approaches to the nozzle and the angles of approach to the nozzle were examined by comparison, it was immediately seen why that burner failed to function. This is something of an important point to develop here. A burner may be a common casting but it must embody certain sound fundamental principles or else it will not function.

To cite an example: When gas is burned in the carburetor of a motor car, the success of such combustion depends on the skill, care and detailed attention embodied in such a carburetor. This is an art in itself. When gases are being burned in the form of a homogeneous mixture and where the proportions between the necessary air and gas are supposed to be automatically entrained; a certain kind of carburetor is required. It may be called a gas burner or a gas mixer, but it is a carburetor nevertheless. The average man who is careful about the use of the gas in his motor car will, as a matter of course, purchase the best kind of carburetor that the ingenuity of the automotive engineer has produced. His bill for gas for the year may not exceed $500. It takes a good deal of traveling to consume $1,000 worth of this gas per year. At the same time there are firms that burn up millions of dollars worth of gas and other fuels per year without using anything that may be called a carburetor. In fact, all the means for such carburetion are made by themselves, but they carry no organization nor laboratory equipped to deal with these values; the pipe fitter is the burner designer. Imagine any individual doing that if he had to burn all this fuel and pay for it himself. Yet this is a condition which is encountered in any number of plants.

There are people who have devoted their lives to the development of apparatus which will properly mix and automatically proportion gas and air. This is not such an easy task. It takes the finest kind of appreciation of dimensional values. In some cases we have to deal with Morse drill numbers. A variation of a few numbers is so minute that the average keen eye can hardly detect this difference, yet it will make a very great difference in the ratios which are brought in, in this way between the gas and air

required for combustion. It must not be forgotten that when dealing with pressures of 25 to 30 pounds of natural gas or 15 pounds of by-product gas, that the most fractional invisible diametric dimension will make an important difference between the input of gas and its proper relation of air. When dealing with such accurate means as a Morse drill number and these very important and exacting dimensions, it is often found that the men around plants fail to appreciate the importance of maintaining the size of the particular drill. When they want to clean these orifices they will remove a plug and stick in a wire and poke into this hole. Since most of these gas orifices are made of brass, it will not take long before they have lost their particular size. Usually when the mixture is off, the very first thing to do is to examine the drills of the orifices which admit the gas into the mixer. In one case it was supposed to be a No. 11 Morse drill and the hole had to be exactingly round. An examination of this particular orifice showed that it was oval and that a No. 2 drill could pass through this hole. No wonder the mixture was all out of proportion and that this particular furnace was not heating well, there being quite a difference between a No. 11 and a No. 2 Morse drill.

It is hard to explain the psychology of men around mills who consider it a great operating difficulty to have occasionally to check up on the condition of the burner equipment. In one particular case where a change was made and a furnace was rebuilt with automatic proportioning devices, there was an important reduction in the fuel used on the furnace and there was an improvement in the quality of the heating, and increased furnace capacity, also increased speed of the milling unit, but on account of the residue of tar and sometimes sulphides which is found in by-product gas, a deposit usually forms in the closely restricted nozzles or mixers, and it is necessary to clean this out from time to time. Invariably the introduction of steam into the gas line and the steaming out of these nozzles will serve the purpose. This is found effective whether the gas be admitted with the high pressure system through a very small Morse drill orifice or whether it be admitted into a much larger space, such as is found in a low pressure mixer. Nevertheless, the steam will be found very effective, and no further cleaning is necessary, providing this steaming is done consistently and regularly. This regularity and frequency very often is a question of the particular physical location of the heating unit in the plant. If it is far from the by-product works, more frequent cleaning will be necessitated. The substances which tend to clog up these small orifices may be some napthalene deposits or light oils, in with some residue of uncleaned tar, and these impurities must be steamed out before they have a chance to solidify. For perhaps half a day they will remain in a somewhat liquid form. For this reason this steaming requirement must not be neglected. Master mechanics and maintenance men consider this a great burden. This is part of the psychology of handling invisible materials. It has never been possible to explain why they will religiously and faithfully lubricate all the milling apparatus, but think it unnecessary to pay strict attention to the proper upkeep and maintenance of valves and delicate mixers upon which the very success of a heating application depends.

To revert to the case just mentioned, of the plant where this new furnace resulted in reduced fuel consumption, increased production and increased heating capacity, the superintendent expressed his satisfaction with this furnace except for one trouble which he emphasized strongly: "If it were only not necessary to clean these gas mixers from time to time." It happens that the machine which this furnace feeds has to be rebuilt, adjusted and readjusted ever so often, yet they think this part of their operating duties, without ever dreaming of complaint. But because it is necessary to open a steam valve twice a day for a few minutes without even interfering with the heating unit and without having to shut down, they consider it a great trouble.

In one mill it was discovered that the main gas cock to a galvanizing furnace was so neglected that it was necessary to use a pair of tongs to move it. This, in spite of the fact that most of the other mechanical equipment in this unit was kept in good shape, but it was impossible to bring home to the subconscious mind of the maintenance organization that it is as vital to maintain the gas burning apparatus in the proper shape as it is to maintain the rest of the mechanical equipment. This trouble recurred and drastic measures finally had to be adopted to cure it.

To bring out these points may seem almost too trivial, but it is not. The purpose of this paper is to bring home the fact that when dealing with the various steel products turned out in the industry, the average laborer or foreman has learned to use the micrometer painstakingly. On tangible things which they can see and touch, heave and pull, they will use a means of measurement to the thousandth or ten thousandth of an inch, but in dealing with invisible materials such as gaseous or liquid fuels, they are content to use the rule of thumb. With gas valves it is one entire turn or one-half turn. Observe an indicating meter showing the flow in volume resulting from the turn or half turn of a valve. In some cases, especially if it is a valve supplying fuel into an open hearth furnace, that half turn more or less may mean the sending in of an additional 25,000 cubic feet of gas per hour. This is one of the reasons why so many organizations have found a great use for an indicating flow meter where the hand on the indicator shows exactly the amount of fuel that is being admitted per hour by the turn of the valve. It is hard for the operator to know by the sense of touch how much fuel is going in, but if he can move his valve and watch the indicator, he is admitting fuel into the furnace by the sense of sight. It is remarkable what a fine degree of adjustment can be derived in this way by the operator. Such an indicator has turned out to be a real money saver. It shows, for instance, the amount of fuel in thousands of cubic feet or gallons per hour. The face of this dial is about ten inches in diameter and is noticeable for quite a distance.

One innovation which has turned out a money saver has been to graduate this dial not in thousands of cubic feet or gallons, but in dollars and cents per hour. There is something very impressive to the mind of the valve manipulator to know that he is sending in $5 worth of gas per hour by the

turn of his wrist, or that he can maintain a proper condition within the furnace by only sending in $3 worth, if the condition of the furnace will permit it.

Innumerable instances can be mentioned where proper burner equipment, embodying the latest improvements within the art, have been instituted on certain furnaces, and within the course of a very few months and sometimes not quite a year, such installations had to be abandoned, and it was necessary to revert to the old method of application. A study of the causes of some of these conditions revealed that the organization itself was not trained sufficiently in their appreciation of values entering into the proper upkeep of such equipment and also into the realization of the proper results.

A good deal has been said about the importance of a gas orifice or the size of a gas nozzle. The same is true of the size of the burner nozzle itself, or the tunnel which it was necessary to incorporate at the end of the burner to constitute the whole of the installation. A burner installation, whether it be one burner or a group of burners, or whether it be a series of burners on a single manifold, is one integral whole. All the different parts, whether it be the gas spud or the size of the gas burner, the size of the manifold or the connection into the burner, the connection of the gas pipe size or the connection of the air pipe size, or the length, diameter or flare of the tunnel, each and every one of these constitute a very important part of the whole. If a tunnel was improperly built into the wall and if the refractory cement from the burner to the end of the inside wall was made of improper material, or improperly mixed in the wrong proportions, or improperly rammed in when the tunnel was molded, then as soon as some of this refractory cement starts to loosen from the end of the burner casting, such casting gets hot and starts to backfire. Very often the burner itself was not properly built into the wall, and some of the back pressure out of the furnace will be allowed to seep back and heat up the burner casting, also resulting in back-firing, and very often beginning the destruction of the burner casting itself. Unless this is carefully watched at the start, this is usually the beginning of the end of this fine furnace installation.

In a good many plants a very superficial inspection will show that the burner equipment is not functioning properly. Hot flue gases leak out along the sides of the burners. Of the multitude of gauges originally provided, few are in order. No one pays any attention to the instrument board, and there are signs of rust and disuse. Unless this condition is corrected at once, the beginning of the destruction of one burner invariably means the undermining of the good condition of all the other burners. Each burner and the entire burner system must be considered as a whole. A simile to such a condition is found in the physiology of the average human being. A defect in the heart begins to affect the liver and kidneys. A certain poison being secreted out of the glands or out of a bad tooth will produce rheumatism, weaken the heart, harden the arteries, etc. These things can and may be avoided. This is only too true of conditions of furnaces in steel plants. Just as it is necessary for all of our well being to have the diagnosis of a good physician to correct incipient manifestations which will be injurious to the general health, so it is of the utmost importance that the metallurgical combustion engineer, who is the furnace physician, locate early the causes of trouble.

In one particular organization where the combustion department was thoroughly trained up to this work and where there had been continual trouble and continual expense for rebuilding of burners, when some of these fundamental early causes were located, the cost of maintenance and replacement diminished to a very negligible item. Yet it used to constitute a sufficiently important item to affect the cost of the finished product.

In some cases the germ of the trouble had been placed there while the furnace was under construction. It is therefore of the utmost importance that the metallurgical combustion engineer be trained sufficiently to primarily inspect the work even though this work had been supervised by some properly accredited furnace contractors. The furnace contractors usually endeavor to do their best on the mechanical work of the furnace structure itself, but it is regrettable to state that not many of the erectors are competent combustion engineers and may not happen to understand the intricacies of the combustion plan which was there installed. It is fortunate for an industrial organization if the furnace erector happens to be a man skilled in the art of the fine application of fuel, but this may not always be the case. Also, the furnace builder is unable to maintain contacts with the operating organization. It takes both the furnace builder and the combustion engineering department to make a furnace a continued success. The former furnishes the body. The latter infuses the soul.

Too many purchasing agents and sales departments buy on price and reciprocity, just as if it were so many bricks and so much structural steel. Yet a furnace bought on that basis may often jeopardize the entire success of the mill. Skill and experience, and not purchase price, should be the basis upon which furnaces are bought. We don't put research men on a piecework basis. The furnace contractor must be encouraged to make a good living. We hire architects and sculptors for their knowledge and skill, and not by the market price of lumber and cement.

The experience of many has been that, regardless of the expense or cost of a furnace installation, it requires only a few months to bring about dissatisfaction with its performance. This may be a broad statement but, although it is not intended to minimize any one's abilities, it states bare facts borne out by the actual experience of those who have been long in the steel business. Any ten machines built will usually perform satisfactorily, unless they be of a type which is a new departure from the art and which introduces new methods. But of the ordinary machines that have been rather well standardized, it is safe to assume that they will perform satisfactorily. How different is the case with furnaces! It is not an exaggeration to state that of any ten furnaces built, not five will perform satisfactorily at the end of a specified period.

In one instance a recuperative type furnace was gradually on the decline. An examination disclosed that the recuperator had not been cleaned for two years. The reasons for the poor performance of

this furnace, on account of these conditions, hardly need to be gone into here. They are obvious. Would a plant-operating superintendent tolerate the neglect of his mechanical apparatus for such a long time? Yet this is a common occurrence in so many plants, when it concerns furnaces. Again it must be stressed that it is the function of the metallurgical combustion engineer to see that these recuperators, whether they be refractory or metallic, be given attention.

The plant-operating organization is only remotely concerned with the preparation of such fuels as by-product gas, natural gas, oil, or tar. This is not so in the case of producer gas. The preparation of this fuel is always part of the problem of the particular department which uses it. In some works there are a number of producer plant groups, and there is quite a variation, not only in the general costs of gasification, but in the quality of such fuel. This constitutes a vital problem in the average organization, and some space shall be devoted to this subject.

There are possibilities always of improving general conditions in the producer gas manufacturing plant. Gas analyses sometimes reveal as high as 10% and 11% CO_2. There is usually found, in addition, a low percentage of hydrogen. In some cases it has been found as high as 12% in CO_2 and as low as 8% in hydrogen, with hardly any hydrocarbons. The B.T.U. value, in some cases, has run to not much over 100 B.T.U. per cubic foot.

A close study will sometimes reveal that the mechanical top of the producer or the attached poker or agitator is not suitably adapted for such a size and depth of producer unit. This is especially found to be the case on a multitude of producers which originally were hand-fired and which were later remodelled with a mechanical feed. When this is the case, the poker or agitator, upon reaching its lowest position, will terminate within the zone which must represent the fire bed of the producer.

In the manufacture of producer gas it is of the utmost importance that a certain thickness of ash bed be maintained, also a certain thickness of fire bed, and above that there must also be a certain thickness of a green fuel bed. These various thicknesses generally depend upon the class and kind of coal used. Suppose the ash bed thickness be about 27 inches deep and the fire bed 8 to 9 inches deep and the green fuel bed from 10 to 12 inches deep, the bottom of the ash bed must be considered as starting from the base of the blast hood. When these various relations and thicknesses begin to vary, the quality of the gas will fluctuate and the gas making process will suffer. When the poker or agitator moves within the hot fire zone, it produces the same effect as if a hole were made in the fuel bed in a hand-fired producer unit. It is generally known that this always unfavorably affects the quality of the gas. It usually means a high CO_2 content in the gas; similarly, a low hydrogen content in the gas will also account for the fact that the steam coming through the blast main into the producer, instead of being broken up into hydrogen and oxygen, is permitted to escape through these holes in the fire bed into the gas stream in the form of water vapor. This water vapor is more harmful to the quality of the gas than even the CO_2, but will not show up in an analysis by the usual means, since such analyses taken by the Orsat are usually taken to indicate CO_2 and combustibles, but are not taken for moisture content.

It has been found that the practice of having someone remote from the producer plant manipulate the steam valve seldom is conducive to the making of a good gas. If, for instance, the open hearth melter controls the operation of the producer house, there is no possibility of holding the producer house operator to account for the variations and fluctuations in the quality of the gas.

It must be remembered that since the ratios of thicknesses of ash zone, fire zone and green fuel zone have such an important effect upon the quality of the gas, that as soon as the producer unit is shut down, these relations will be immediately destroyed, and it may take the gas maker the best part of a turn to rebuild the various ratios of thicknesses in order to reestablish the conditions under which good gas was made. The producer gas maker is not a magician and he cannot rebuild the condition of this unit in a moment. It is therefore of great importance that by a system of signals the gas maker be advised of any changes in the demand that may be made upon him, but he must have a reasonable time to enable him to either slow down his feed or increase it in order to anticipate either an increasing or a diminishing demand. A regulator which really functions will be found to be a great help.

There is another very important element to be considered in the operation of a producer plant. This constitutes a considerable loss in fuel and does not contribute to the pleasantness of living conditions in the producer house. These are leaking poke holes. Considerable quantities of good, useful gas are lost by the practice of the gas makers of continually removing the iron balls from over the poke holes, permitting a stream of useful rich gas to escape into the gas house. This practice should be discouraged. It tends towards warping the seat of the poke hole or of the ball itself, so that eventually the ball which is supposed to be its seal, no longer completely closes up this poke hole. Some suitable castings with closer fitting seals will be found very useful. Instead of the practice of opening the poke holes and permitting the escape of gas, a better practice would be the consistent and periodic use of measuring rods. These measuring rods represent the length of the entire producer down to the base of the blast hood. By inserting this measuring rod into the producer for about three minutes, the gas maker can readily see the depth of his ash bed, the thickness of his fire bed and also the thickness of his green fuel bed. After these various thicknesses have been determined, it is easy to mark them on the floor opposite each producer, and the measuring rod, upon being withdrawn, is placed on the floor and compared with the marks which have been predetermined. If this be followed three or four times to the turn insead of opening the poke holes perhaps 100 times to the turn, it is surprising what an improvement can be made in the quality of the gas. In an organization where this method was introduced, it has been carried so far that each hour these measuring rods are used and a record of the various dimensions and ratios found on each producer is sent, at the end of each turn, to the office of the superintendent of this department.

When, earlier in this paper, the question of the plant organization psychology was treated, mention was made that it has been very difficult to get plant and maintenance organizations to appreciate the value of upkeep of furnace apparatus and equipment. This usually is an index as to how well the metallurgical combustion engineer is performing his function. If furnace apparatus, gauges and instruments are neglected, it is an indication of one of two things: either that there is no well organized metallurgical combustion department, or that such department is not functioning.

If the plant organization fails to realize the importance of proper heat application, or if managements are unsympathetic to the expenditure of these necessary moneys, it is unfair to blame either the plant organization or the management. Observe the general alertness and quick adaptability of this same organization on matters mechanical or on newer developments within the rolling art. If the organization cannot be made to see the importance of the metallurgical side, it is rather an indication that the metallurgical combustion department have not put over their story and have not sold the importance of their function. Experience has proven that managements and plant organizations are only too eager to co-operate as soon as they can see some valuable improvements either in the fuel costs or in the quality of the product. It is necessary, therefore, for the metallurgical combustion engineer not only to perfect himself in the skill of the engineering phase, but in maintaining a very close and sympathetic contact with the plant organization.

When a plan is being considered, the work which subsequently may result would get on so much smoother if conferences were held with the various departments concerned. It is very important in the consideration of such plans that the operating organization, the metallurgical department, the engineering department and some representatives of the management be brought together for a free and open discussion of all these problems. Each man will later on feel that he has had a hand in the development of this plan and it is but natural that each of these departments will be pleased to co-operate to make any work of this kind a success. Some organizations that have learned to follow this work in a co-operative spirit, seeing the results from this careful planning, have even gone so far as to lay aside a budget equal to a certain percentage of the annual fuel bill, for the use of the metallurgical combustion department pay roll and for research and developments within the art.

The metallurgical combustion department can also do a great deal to enlist the interest of the entire organization in their work, by preparing monthly a tabulated chart showing the practice and various efficiencies of the different departments using fuel for metallurgical purposes. If each department superintendent were to receive a comparative monthly statement on a standard form showing his progress from month to month as to the fuel used on a basis of millions of B.T.U. per ton of product for each particular process, he will have an incentive to call upon the metallurgical combustion department for help.

The plant organization will learn to avail itself of this combustion department in the measure that such a department makes itself useful, and in this way it will not take very long for a live combustion department to make itself a vital part of the operating function of the organization.

Report of A. I. & S. E. E. General Lubrication Committee

During the Fall of 1930, the Lubrication Engineering Division of the Association of Iron and Steel Electrical Engineers sent out a questionnaire to the Iron and Steel Industry in general covering general plant lubrication. In doing this it had one objective only, that was to gather lubrication data, so that after tabulation a general idea of the various problems could be easily attained.

Roll Neck Lubrication

The outstanding problem appears to be roll neck lubrication and in this report some of the high spots will be touched upon and comments made in the final paragraphs.

Lubricants Used

A few mills use suet as in years gone by. In a few instances soluble bag grease is used, in some others a soluble block grease, but the major number use the ordinary roll neck grease composed of a high soap content with a binder to make it plastic, and compounded with oils, tallows and some kind of a filler—either graphite, mica or some such material to assist to withstand heat and pressure conditions, while others are using a soft high tallow content grease where force greasing systems are used.

Application of Grease

The general use is to pack the grease against the neck either in a mass or in a grease retainer. The retainer being made out of light metal or wood. In some instances where cast steel or iron scale guards are used, these are used as a grease retainer. Where force greasing systems are used, the grease is forced into grooves or into a wiper box which rests against the neck. Where soluble bag grease is used some pack it against the neck while others support it on top of the neck so that the water can shower over it.

Bearing Material

The majority of mills use a lead base bearing metal with bronze metal inserts of different designs —some of these bronze inserts are simply bronze

strips extending over the radius of the collar—others are cast solid, the bronze acting as a thrust collar with two or three longitudinal strips bound together at the outside end, it being a part of the casting—again on smaller mills the bronze casting is perforated, these openings being filled with babbitt. In many mills a solid bronze bearing is used, while in others a solid Babbitt metal bearing is doing good work.

There is a constant effort to improve the bearing metal. The vendors of babbitt and bronze metals are in touch with the operating conditions, consequently all are bringing out heavy duty babbitts and bronze metals, for all operating conditions. In fact, at the present time there is a metal for all conditions.

Anti-friction bearings are being used in many instances and are exciting a great deal of comment by all mill operators. They are proving satisfactory under the most trying conditions and have many qualities which eliminate constant troubles and future worries.

In many instances under proper working conditions wood is being used in the place of metal, and where the wood is used it is working out much more satisfactorily than the expectations of the operators.

Scale Guards

There are many scale guards used—almost as many as different types of mills and the ingenuity of the operator—In larger mills the circular cast guard resting on the sides of the bearing, in smaller mills they are made of plate. In all instances the guard is flanged out to fit the radius of the roll neck. Others use a guard with a wood section fitting against the radius of the neck with an opening in the side so that grease can be forced against the neck. In fact as noted above the type and style are many, all doing more or less good service.

Grooving of Bearings

There are many types of grooves used. These are used where a force greasing system is used. Some are using two grooves which start near the outside end of the bearing and continue on and into the thrust collar. These are generally used where two connections from the greasing system are made, as in reversing mill operation. Others use two grooves similar to the above type but connected together so that one feed from the grease unit can be used. Others put a spiral or "S" groove in the collar. This groove is furnished with grease, as in all other types, through a hole drilled through the body of the bearing. The grooves are deep and wide and the sides heavily chamfered to keep from wiping or scraping the grease film off the neck.

This questionnaire has brought out many factors which hinder good lubrication—such as, poor water conditions, either dirty, very warm, or acid content. In every instance different types and densities of grease must be used. Again necks not protected against scale, uneven balance of roll pressure, and over working pressure on the roll bearing, as well as roll necks not protected against scale dust.

It also brought out the common practice of babbiting bearings on a mandrel, these bearings not being machined are very uneven and when first put into the mill have practically no bearing surface. The real bearing fit being made by the first few minutes of use, causing high friction heat and neck wear, during which time the lubricant has no chance whatever to function properly. Also if the mill is not in line with the pinion necks, due to the different size of the rolls, the coupling boxes will, if the wobblers are worn, cause a wobbling motion which pounds out the bearing, also in many instances causes an end thrust which quickly wears off the bearing thrust collar.

True lubrication being a proper film of the proper lubricant, properly applied, therefore every effort should be made to keep this proper film intact. We all know that general mill practice is to produce as much tonnage as possible and in doing this the roll neck has been neglected in many instances. Knowing that there will be a stop sooner or later during which time the greaser can pack the neck it is not fully realized that if the neck has been neglected and it has become scratched that no matter how good a bearing fit may be it does not have an even chance to do its work. Again if a bearing has been hot it has without a doubt a skin of glassy hard metal that will not assist in keeping a proper film. Also the bearing metal is liable to disintegrate and small particles will flake off and in many instances these flakes will lodge on the bearing surface, making a high spot which will cause a high heat and an uneven surface. At these points the pressure is increased which causes the film to be broken and a high heat developed which cannot be reduced until the bearing is changed or surface scraped.

If the neck should be worn uneven and a new bearing installed there must be developed a friction heat until the bearing has conformed to the shape of the neck—during this time, no matter how good the grease may be, it does not have an even chance to perform its proper function.

As the object of a rolling mill is to turn out a proper section and to keep the mill practice as high as possible every effort should be put forward to preserve the bearing and roll neck. To do this it is the present aim of all mill operators to do all that is possible to perfect the lubrication and its practices. Consequently, during the last two or three years several automatic greasing devices have been brought out, all rendering excellent service in reducing grease consumption to quite an extent. Saving of lost time in stopping for greasing and tightening the mill is an item to be reckoned with. With these new systems many bloomers run several days without a single stop for greasing and adjusting the mill. In one instance the time saved in stops has amounted to $40,000.00 in material production.

Safety Factor

The safety factor is a great item in favor of the new greasing devices. Men do not have to climb around the mill and into unseen places. For instance, in one plant it was reported that a man lost a foot due to the operator starting the mill not knowing that the man was greasing a certain out-of-the-way bearing. Together with the Safety Factor it has increased the Morale of the men—all mill operators know that in order to grease a mill properly he must get into the muck and dirt to do it, in doing this the man must necessarily destroy his shoes and clothing. Now this useless waste and expense to the greaser is eliminated and his general appearance is much improved—also the home ties are more pleasant due to the fact that his clothing is much cleaner.

Testing of Lubricants

It is recommended by the Lubrication Engineering Division of the Association of Iron and Steel Electrical Engineers that all manufacturers and distributors of lubricants install sufficient equipment to make the proper tests of their products before offering them for any application in the Iron and Steel Industry. The present practice of trying out products offered by the distributor to the customer produces the following results:

1. An operating expense which is absorbed by the customer.
2. Delays through faulty application
3. Bearings ruined by the improper use of lubricants.
4. Loss of production.

While some manufacturers make preliminary tests, further effort should be made to amplify these tests to the extent that in the field of operation, the application of lubricants will not be regarded as experimental.

Summary

All that has been said in this report brings out the great interest in perfecting roll neck lubrication. It has brought the problem direct to the grease manufacturer. He must develop new greases and special greases to meet all conditions and in doing this he must not only be a grease maker but he must accept suggestions from the operator who in the last analyses must bear the grief of poor operating conditions.

It has also brought out this fact, that in order to produce good grease, that the grease must have proper lubricating qualities, not simply something to be seen against a neck but something that will form a proper film on the neck. Heretofore competition in price has worked against the general quality of lubricants but now we must have the right lubricant irrespective of the price per pound.

It is acknowledged that the automatic grease system or device manufacturer is aiming to constantly improve his apparatus. He knows full well that they are in their infancy and that the mill operator, together with the lubrication engineer, will be able to offer the manufacturer of systems and devices many practical suggestions and ideas for improvement. A closer form of co-operation is recommended.

The two greatest draw backs to automatic pressure systems are these, viz., grease that will cake in the system—and small particles of dirt in the grease. The first objection can be remedied only by the grease manufacturer but the second is almost wholly up to the operator. But with the barrel pump most of the dust danger can be eliminated, even with the barrel pump there is some grease that must be scraped out of barrel and it is at this time that the dirt has a chance to contaminate the grease.

The Art of Lubrication is and will progress and the Lubrication Engineering Division of the Association of Iron and Steel Electrical Engineers will do their part in furthering the advancement of this art. With the help and cooperation of the Lubricant and Device Manufacturers it is hoped to establish a clearing house for the lubrication problems confronting the Iron and Steel Industry.

Our General Lubrication Committee has now instituted a Lubrication and Device Development Committee.

The formation of this committee will be similar to the Electrical Developments Committee and will have to do with new developments in the Lubrication field. Committee to be composed of the manufacturers of lubricants and devices for application, filtering apparatus, etc. Lubricant or new equipment developments will be broadcasted through this committee. It may be possible to broadcast this information through the committee quicker and in a more concise form than through individual efforts of the manufacturer's themselves and be of some real service to the steel industry.

Personnel of the Committee to be formed from manufacturers who are represented in the membership of the Association. Every member of this committee must be a member of the A. I. & S. E. E., and the personnel of this committee will be published in the July issue of the Iron and Steel Engineer.

Our next conference will be held in Pittsburgh in October at which time the Lubricant Manufacturers will be invited to present their latest developments in Lubricants for Roll Necks.

Lubrication of Electrical Apparatus Used In Steel Mills

By J. L. BROWN*

The lubrication of machinery is of necessity an age-old practice, but evidence is not lacking that much remains to be learned about getting the right kind of lubricant in the right place in the best way to do the most good.

A lubricant is useful chiefly in separating relatively moving metal surfaces which would otherwise rub upon one another often under heavy pressure. Such relatively moving metal surfaces, commonly called bearings, form one of the problems which electrical machinery has in common with many other types of machinery. However, in an electric machine it becomes much more serious because of certain inherent features of design peculiar to this type. The presence and nature of insulating materials and the practice of passing ventilating air over the insulation surfaces of the machine greatly complicate the problem of electric motor lubrication.

The greater percentage of all the smaller bearings

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of electric machinery now in service, and practically all large electric motor bearings, are of the plain or sleeve type. Large sleeve bearings are usually "split" into upper and lower halves, forming when placed together a complete cylinder. Many of the smaller sleeve bearings are also of this type, the remainder being continuous one-piece cylinders.

For continuous operation, these bearings when properly designed, are ideal. Enormous weights are sustained with a minimum of friction by the simple expedient of introducing oil between the bearing and the shaft at the side opposite that carrying the load. The rotation of the shaft rolls the oil particles under it where they support the load under pressures sometimes as high as 500 pounds per square inch and commonly as high as 150 pounds per square inch. The feeding of the oil is made automatic by suspending a light brass ring on the shaft and allowing it as it rotates to dip into a reservoir of oil conveniently placed below the bearing.

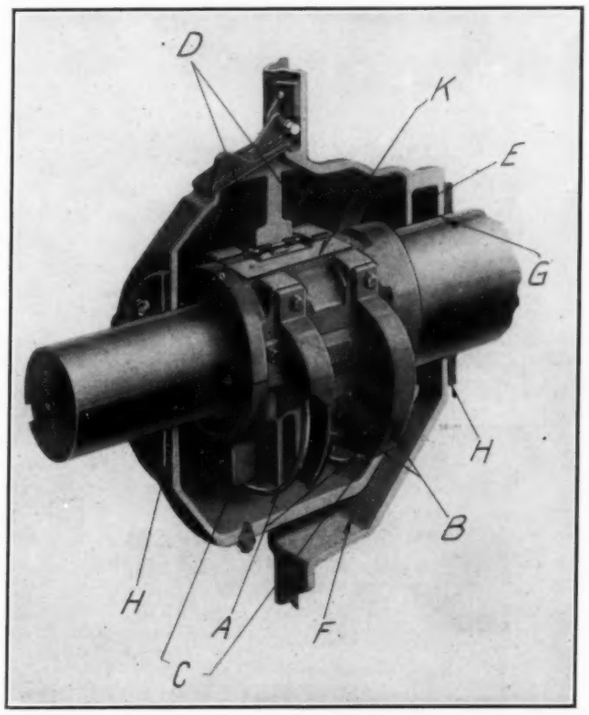

FIG. 1—Westinghouse Sealed Sleeve Split Bearing.

On large apparatus the split feature is particularly advantageous from the standpoint of disassembly of the apparatus for repairs because the large couplings or other devices pressed or shrunk on the driving extension of the shaft, and which would otherwise have to be pressed off, may remain in place even when the rotor is completely removed from the machine. Furthermore, to repair the bearings themselves it is unnecessary to remove the rotor at all or even to disconnect the coupling.

The bearings are simple, simply repaired or renewed, and nature's own anti-friction medium is pressed into service with a minimum of "harness" and with maximum effect. The marvels of the mechanism of lubrication is a story of compelling interest. Within a few inches of the circumference of this simplest of constructions the oil pressure is built up from zero to as much as 500 pounds per square inch without pump pistons, centrifugal runners, valves or gaskets, and at even low rotational speeds, so that even the most massive rotors of main roll driving motors actually as well as theoretically float on oil.

Interesting as is this side of the story, we must pass on to the problem of practical difficulties, and the consideration of those features of the lubrication problem which are not automatic and to which, therefore, we must apply our intelligence and skill in order to achieve satisfactory performance of our electrical apparatus.

Failure of the fluid film which occurs in the plain bearings of some apparatus (roll neck bearings, for example) due to the building up of excessive unit pressures, is not normally encountered in electrical machinery, as it is usually feasible to provide adequate bearing area. The chief difficulty arising in electric motor lubrication is in preventing oil from escaping from the bearing housing and spreading over the insulation with destructive effect.

The persistence of oil in filling and escaping through minute crevices, and in spreading over surfaces—especially rough or dirty surfaces—is a great asset from the standpoint of effective lubrication but it has been responsible also for large monetary losses due to direct maintenance expense in rewinding apparatus and to expensive shut-downs and delays in production. The suction produced adjacent to the bearing housings by the use of artificial ventilation has greatly accentuated the tendency of the oil to escape and it is only within the last few years that we have learned how to combat effectively these tendencies without in any way impairing the lubricating efficiency of the oil. Even in cases of serious leakage the amount escaping in an hour or even a day may be very small but the aggregate in a year's time may be sufficient to be very destructive. It is

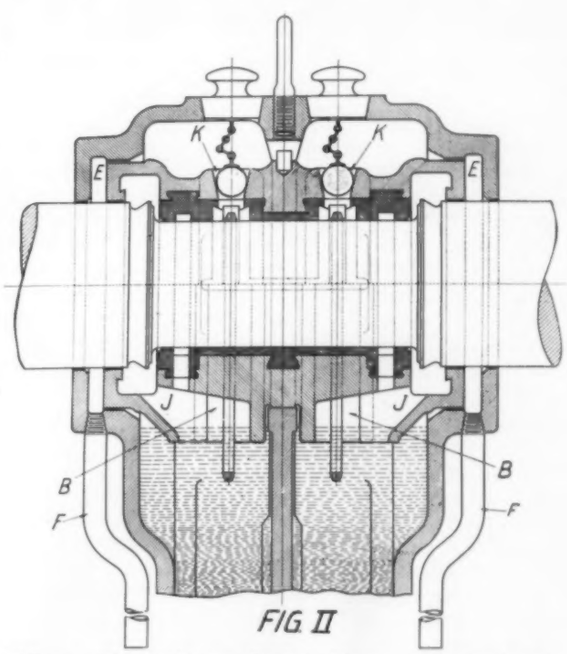

FIG. 2—Westinghouse Sealed Sleeve Split Pedestal Bearing.

essential, therefore, to permanency of the machine and its parts that oil leakage be eliminated entirely.

Oil leakage from split bearings, which entail of course split housings, has been particularly bad and particularly difficult to eliminate. Oil particles lodging on the upper interior walls of the housing collect into a film which runs down and finds ready egress through the capillary space between the upper and lower halves of the housing. Not only so, but this space acts as an axial duct to convey the escaping oil to any point where leakage occurs most readily, as where the proximity of a ventilating fan attached to the rotor results in appreciable suction, inducing the oil to escape into the air stream.

It has been recognized for a long time that the oil rings have been responsible for a great deal of oil splashing in the bearing housings, and the bearings have been fitted with guards shrouding the rings so that the oil splash would not be directed at the split or parting. Resort has been had to closing the parting with a sealer such as shellac or plumber's cement and many other schemes have been tried with only limited success.

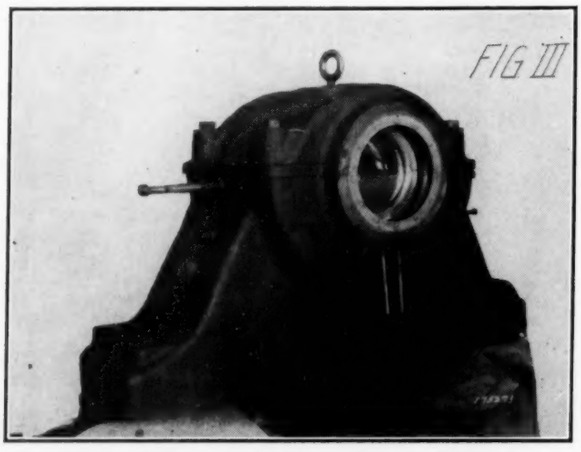

FIG. 3—External View of Westinghouse Sealed Sleeve Split Bearing Pedestal.

Analysis of the situation disclosed the fact that if the interior walls of the housing could be kept as dry during operation as they are when the apparatus is not in use there would be no leakage during operation even as there is no leakage at standstill. Further investigation led to the discovery that even carefully guarded oil rings create a minute spray, too finely divided to be seen or to be appreciably affected by gravity. These minute particles float out from the rings and through the air space within the housing, finally lodging on the housing walls or are borne by air currents out along the shaft into the motor.

Notice how the design shown in Fig. I absolutely prevents the escape of any oil particles from the oil rings A into the housing chamber D. Not only are the oil rings guarded but they are completely enclosed within chambers B (shown partially cut away) which are open at no point above the level of the oil in the reservoir. The lower edges C of these chambers are about ¾" below the oil level. The sight holes at the top of the bearing for inspection of the oil rings are closed by a spring hinged and gasketed cover K located in a recess draining back into the interior of the bearing. Dust proofing washers H perform no part in preventing oil leakage as air currents may pass freely through the housing without danger of carrying with them any oil vapors. The inner walls of chambers D are at all times quite dry. The parting between upper and lower halves requires no sealer and may be open any amount without danger of oil leakage. The principle throughout is complete isolation of the oil rings or other spray forming parts of the bearing from the main housing chamber, thus simulating in this chamber, even during operation, the conditions obtaining at standstill.

Attention is directed to the chamber E which separates the inner end of the bearing housing from the interior of the motor and communicates with the

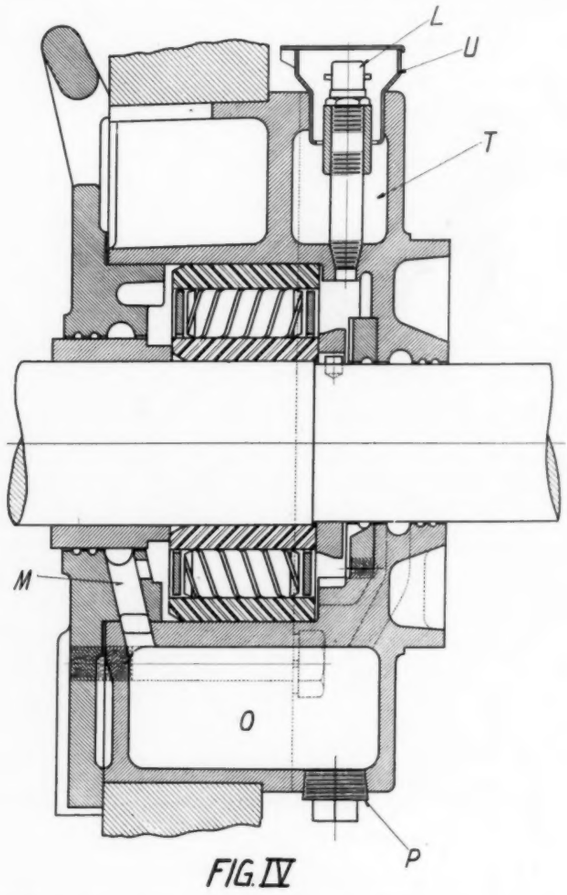

FIG. 4—New Westinghouse Mill Type Motor Roller Bearing Housing Arranged for Grease Lubrication.

atmosphere through a duct F below the oil reservoir. By this means the air pressure established at the inner end of the housing is very slightly less than atmospheric, thus reducing the suction tendency to oil leakage to a very low figure regardless of the windage conditions inside the motor. Escape of air into the motor through the annular clearance space G is supplied at low velocity through the duct F instead of through the bearing housing.

Figure I is a perspective drawing of the Westinghouse Sealed Sleeve Split bearing. It has been giving perfect performance over a period of several years, so that it may be confidently stated that if

this combination of features be applied there is no case of stationary motor bearing oil leakage that cannot be completely corrected.

Having achieved success with this design of leak-proof split bearing, a line of pedestal bearings has been developed for larger machinery incorporating these features. A cross section line drawing is shown in Fig. II. In this figure B are oil ring chambers. Enclosed oil return chambers are shown at J. Individual sight hole closing plugs K are used instead of a spring hinged cover. The inner wall of the annular bypass chamber E at both ends of the pedestal is formed by the ends of the bearing casting itself. Communicating ducts from these chambers to air at atmospheric pressure take the form of twin pipes at F.

As journal speeds increase beyond 1800 feet per minute, the normal flow of oil through a ring-oiled bearing is often insufficient for conducting away the heat, so that for the higher journal speeds, flood oil lubrication is used. The pedestal bearing illustrated in Fig. II is adapted to this type of lubrication, which can be used with or without oil rings. This type of lubrication involves the use of a direct driven or motor driven gear pump and oil cooling tank or radiator. Fig. III is an external view of one of these pedestal bearings.

A number of applications of auxiliary motors in steel mills involve the movement of the motor bodily as in crane service. The rapid acceleration and deceleration of the crane or other apparatus often results in escape of oil from the motor bearings, some of which finds its way on to the commutator and windings of the motor. Then, too, there has been an objectionable amount of oil leakage even in the case of stationary motors from causes described for larger motors in an earlier paragraph. In some cases, also, heavy grease from the gear cases has flowed into the bearing housing settling into the bottom of the oil reservoir and preventing operation of the oil rings, resulting in failure of the bearings and subsequent damage to armature and pole pieces. As a result of such difficulties considerable interest has developed in the application of ball and roller bearings to auxiliary motors. This new development has brought its own problems, and among them the lubrication problem has been one of the most outstanding.

In substituting roller bearings for sleeve bearings in auxiliary mill motors, we did not follow the practice of "rather bearing those ills we have, than flying to others that we know not of." We have since found out what this new set of ills is. To put it simply we adopted roller bearings to get rid of oil. In adopting grease instead of oil we encountered three sets of new difficulties as follows: (1) grease consistency; (2) application of grease to bearings; (3) destructiveness of the grease to the bearings themselves.

As ball and roller bearings are designed with very small running clearance, any particles of foreign matter passing between the rolling members and the races have the effect of overloading the bearing so that greases employing fillers such as mica or flake graphite are a menace to bearing life. Some other greases have an acid content or, after a period of operation, liberate acids which attack the polished surfaces of the bearing parts, rendering them unfit for use. A third phase of grease destructiveness is the tendency in practically all greases—some more rapidly and others less rapidly—to break down or separate into soap and oil. The oil being used or evaporated or otherwise escaping, leaves a soapy residue which cements the bearing parts together or fills them with a non-lubricating and abrasive residue which very soon thereafter destroys them altogether.

Somewhat related to this last phase of grease destructiveness is the problem of application of the grease. The question of "how much and how often?" is an ever present one. The old overflow gauge with which we are familiar in sleeve bearing practice is

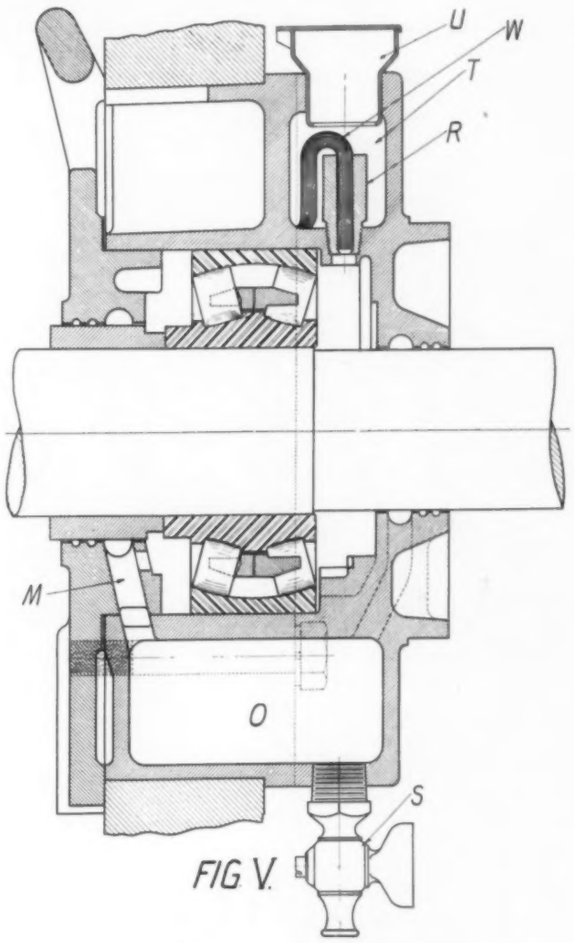

FIG. 5—New Westinghouse Mill Type Motor Roller Bearing Housing Arranged for Oil Lubrication.

rendered useless by the non-fluid nature of the grease. Especially as ball and roller bearings actually use a relatively small amount of grease over a period of time, overfilling is the rule rather than the exception. The presence of too great a quantity in the housing results in violent churning of the grease, especially at high speeds, entailing overheating of the bearing and much more rapid separation of the grease than would otherwise occur. The one advantage of overfilling—namely the excellent seal against the entrance of dirt even with otherwise inadequate closures—is further overbalanced by the

old trouble experienced with oil lubrication—leakage into the motor. This occurs more readily when an excess quantity of the lower melting point greases are used, as the normal temperatures of asbestos insulated motors are often high enough to reduce these greases to the consistency of oil. To the extent that the grease being used breaks down into its component parts, the necessity arises for periodic disassembly of the bearing housings and thorough cleaning of the bearings of the non-lubricating residue of worn out grease. This is an annoying and expensive performance but is the alternative to complete bearing replacement.

As is well known, there is a wide variation in the types and consistency of greases. Furthermore, the consistency of practically all greases changes with the temperature. This characteristic is undesirable and unavoidable and is especially troublesome in outdoor applications where the temperature varies from summer's heat to winter's cold. The variation in consistency of different greases at any given temperature is intentionally brought about to suit the widely varying uses to which the greases are put, for of course greases are used for many other purposes than lubricating ball and roller bearings.

It becomes confusing enough, in addition to selecting a grease which will be suitable in other respects, to choose one with high enough melting point and suitable consistency at the temperature at which it will be used for any given type of bearing. But as types of bearing also vary widely and for this reason have different requirements as to the type and consistency of grease the problem becomes still further involved. And as if this were not enough the factor of speed also enters the equation.

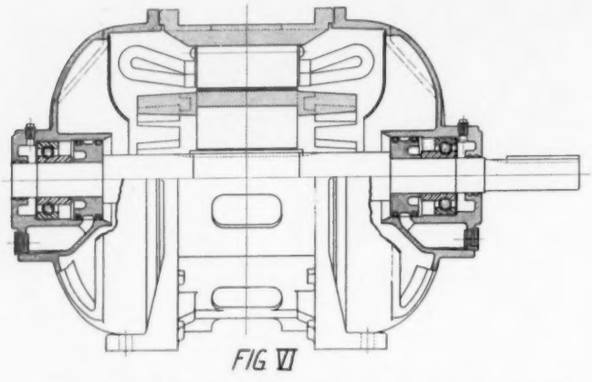

FIG. 6—Longitudinal Sectional Assembly of Squirrel Cage Induction Motor—Ball Bearing Type.

Tearing of the viscous grease film as the bearing rotates consumes a certain amount of energy and as this process is accelerated with increasing velocity, a very formidable generation and accumulation of heat results. The velocity may be so high that the grease used will not be able to penetrate amongst the rolling elements so that they may run without lubrication, resulting in early failure. This is true to such an extent that there is a speed for most roller bearings used in steel mill motors beyond which it is not practical to achieve successful performance with grease of any kind, and oil lubrication must be resorted to.

After all it is an oil film that is needed for lubrication. That part of a grease which makes it non-fluid is only a sort of sponge that soaks up the oil and holds it up to the surface needing lubrication. In view, however, of the bewildering maze of difficulties which beset us contingent upon the use of grease perhaps we shall find ourselves increasingly turning back to oil. There should be some way out of the dilemma. One large user of ball bearing motors in Michigan has put it to me in this way: "You have made such a good job of the lubrication of your Sealed Sleeve bearing motor, I don't see why you can't make as good a job of a ball bearing motor." Perhaps we can. Indeed! Perhaps we have. But, as in **all** our efforts in the line of electrical machinery, we should like you, the users, to judge as to the excellence of our product, we present in Fig. IV our latest in bearing housings in which we have sought to incorporate the answer to many of the questions that are being asked about the lubrication of roller bearings in mill motors.

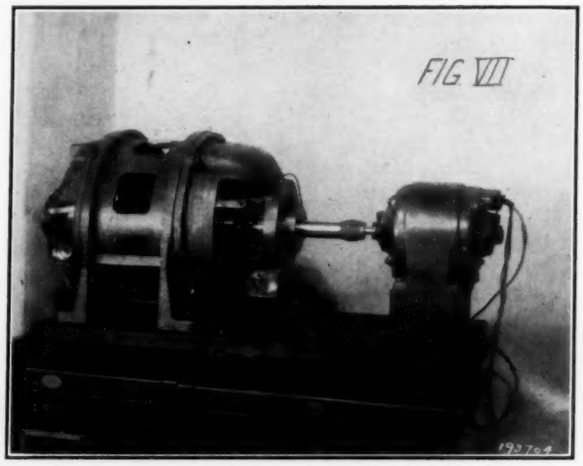

FIG. 7—Exhibition Model of Ball Bearing Motor Arranged to Show Path of Lubricant from Point of Entry to Sump Provided for Surplus.

If grease is to be used for lubricating roller bearings, the design should be arranged so that any surplus will automatically escape and thus avoid churning and its attendant evils. The fresh grease entering should be compelled to pass into and through the bearing, lubricating it and cleansing it of older grease before it can pass out as waste, thus keeping the supply of grease in the bearing itself always fresh, and prolonging the period before cleaning is necessary.

Precisely this arrangement is illustrated in Fig. IV. Grease may be introduced through fitting L entering the housing at the outer end of the housing. At the inner end of the housing an escape port for surplus grease is shown at M. This communicates with a surplus grease reservoir O below the bearing which may be drained at convenient intervals through outlet P.

As some of the problems we have attributed to grease are closely associated with the size and design of the bearings themselves and the speed of operation, even an ideal greasing system will not remove every difficulty encountered, and resort must be had to the use of a different type of lubricant which will be able to penetrate amongst the rolling members of even large bearings running at the higher speeds. Petrolatum is a pure petroleum

product of the consistency of a light grease at ordinary temperatures. It is a good lubricant, and as it contains no soap it cannot deteriorate to produce a residue which is destructive to the bearings. It can be introduced to the bearing housing by the same means as grease and any surplus can escape by any means provided for grease. In the past its use has been limited because it melts below motor operating temperatures and the problem of oil leakage has seemed to attach itself to the resulting fluid. Being of low viscosity, however, in its fluid condition it will satisfactorily lubricate the larger and higher speed roller bearings which are much less satisfactorily lubricated by grease.

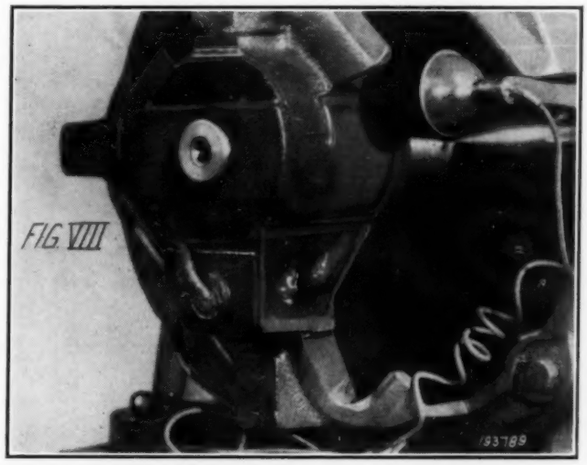

FIG. 8—Showing Average Grade of Petrolatum By-Passed to Grease Sump from Overfilled Bearing.

When used in the bearing housing illustrated in Fig. IV, the danger of leakage is practically eliminated by the fact that all but a generous film of the liquid petrolatum over the various parts of the bearing is by-passed into the lower reservoir. It is possible, therefore, to make an arbitrary lubricating "set-up" of adding definite amounts at stated intervals without fear of over lubrication and leakage, it being only necessary in addition, to withdraw the by-passed surplus from the lower reservoir periodically.

As petrolatum, which is liquid at motor operating temperatures, can be successfully used in the new housing, the question will occur to all "Why not oil?" Well, why not? Let us refer to Fig. V in which the alemite fitting and grease pipe have been replaced by a simple felt wick feed fitting R, and a drain cock S added to the outlet hole in the lower reservoir. Upper reservoir T will contain oil introduced through fitting U whence it will be slowly and continuously syphoned through the felt wick W. The amount of lubricant used up or lost by the bearing is very small and will be replaced by the slow feed of filtered oil entering from the upper reservoir, which is of sufficient size to contain several months' supply. Surplus oil collecting in the lower reservoir should be drained off through drain cock S and may be salvaged for further use.

As general purpose motors are supplied in some quantity for certain steel mill applications, a cross section line drawing of a typical open squirrel cage ball bearing induction motor is presented in Fig. VI. The bearing lubrication system employed in this motor is quite similar to that described for the new mill motor and has been in satisfactory operation for some time. The inner ends of the bearing housings may be closed with the piston ring seal as shown or by the cover construction employed for the mill motor housing. For oil lubrication the supply reservoir takes the form of a metal, wick type cup (not shown) screwed into the hole in the top of the housing with or without an extension pipe.

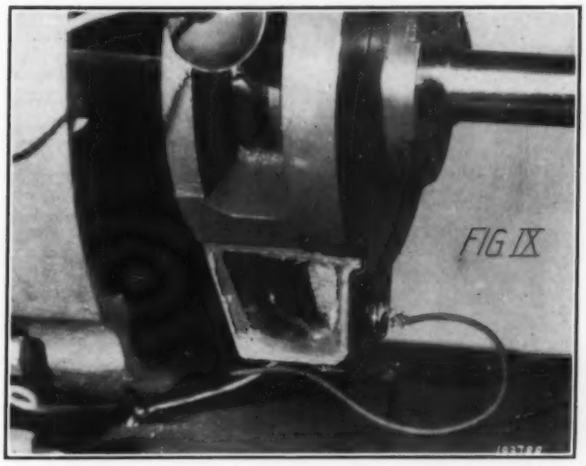

FIG. 9—Showing Viscous Lubricant By-Passed to Grease Sump from Overfilled Bearing Housing Through Restricted Outlet.

An exhibition model has been constructed as shown in Fig. VII in which portions of the housing have been cut away and closed in with glass so that the path of the lubricant may be traced. Fig. VIII shows the front end housing overfilled under pressure and the surplus lubricant being by-passed through the relief ports into the lower reservoir. Fig. IX shows a much more viscous lubricant being by-passed to the lower reservoir through much more tortuous passages. Extruded portions of the lubricant are plainly visible formed by passage through the escape ports. Even in these rather extreme experiments in overfilling there was no escape of the lubricant into the interior of the motor.

In conclusion it may be stated that in this paper there has been no attempt to exhaust the subject of lubrication, even of electrical apparatus, but simply to add to the general sum of knowledge a small contribution which, it is hoped, will prove both interesting and useful.

Motor and Control Equipment For Cold Strip Mill Drives

By F. MOHLER*

PART I
Cold Rolling

Considerable energy has been expended in recent years in experiment and research on the study of the cold rolling of strip steel. Many articles have been written in the various Trade Journals and several papers, dealing with cold strip rolling problems, their solutions, and new developments in the industry have been given before the Institutes. Comparatively little publicity, however, has been given to the development of motors and control, which must follow in the footsteps of new rolling practices.

Although much is still to be expected, considerable has been done toward increasing the industry's knowledge of "pickling" and preparing the steel for cold rolling; the allowable reductions and number of passes; heat treating and annealing; methods of obtaining accurate gauges and definite degrees of hardness; and reliable tests for determining the quality of the finished product. With this knowledge and progress, the field of application and, likewise, the actual uses have grown rapidly. The cold rolling of a piece of steel for a particular use, obtaining a certain gauge, hardness and quality, has become a science.

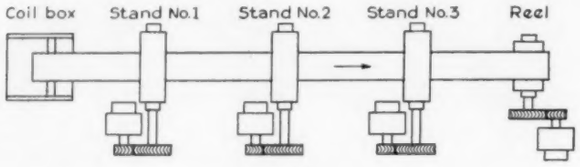

Fig. 1
Schematic layout of a three stand tandem cold strip mill with reel

A detailed discussion of the foregoing is beyond the province of this paper. However, it is impossible to talk intelligently of motor and control application without thought of the problems involved in rolling. Too often, a motor is considered merely as a machine for transforming electrical energy into mechanical work, and control merely as a valve for starting and stopping this phenomena, without regard to special desired characteristics.

A very brief description, in the broadest sense, of the process from an operating standpoint, may prove of interest and serve to refresh our minds.

The first task, of course, is to prepare it for rolling. Rust, scale, and foreign material must be removed—first, to avoid rolling these impurities into the steel and thereby marring the finish and quality; and second to prevent injury to the very accurately ground and highly finished rolls. The modern tendency is to employ a continuous pickling machine. In one continuous process the strip is uncoiled, sheared, "stitched," "pickled," cleansed, "treated," sheared, and recoiled ready for delivery to the cold strip rolling mill. This apparatus falls into the class of auxiliaries and will not be further discussed.

The rolling mill may consist of a single stand of motor driven rolls or a group of several stands in tandem (see Fig. 1). A tandem mill passes strip directly from one set of rolls to the next without intermediate coiling or reeling. Figures 2 and 3 show some typical general views of tandem mills. The final stand is followed by a coiler or reel for winding up the rolled strip. Figures 11 and 11a show general views of such reels.

The arrangement of stands depends upon the gauge and width, as well as the desired quality, of the material rolled.

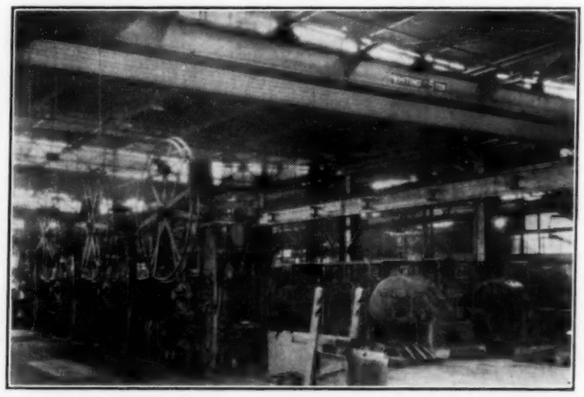

FIG. 2—General view of a 4-high tandem mill driven by four 500 h.p.—400/800 r.p.m.—250 volt motors.

If a curve is plotted between gauge and width, the commercial limit in gauge for hot strip mills is found to vary approximately in a straight line from about .068″ for 50″ wide strip to .038″ for 10″ wide strip, and from this point again, in a straight line, to .026″ for 1″ wide. Therefore, the total reduction necessary for any particular width will be roughly, the difference between the commercial limit as given in the above proportion and the desired finished gauge. The present normal limit of reduction in a single stand is about 60% (that is, the cross sectional area is reduced 60% in one stand). Of course, this allowable reduction is dependent upon the mill and roll design, as well as upon the tension applied. It is also a well known fact that the steel becomes harder after each pass, and a smaller reduction must be taken in the second stand, etc. In a four-high mill, which has been carefully designed, the allowable reductions may be in the neighborhood of 60% for the first stand, 40% for the second, and 20% for the third. More frequently, however, these figures will be 50%, 40% and 20% respectively. For our purpose, however, this will give us an idea of the num-

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ber of passes necessary for a particular gauge and width. For the layout of a modern mill, constant attention is given to the elimination of handling—hence, the eternal striving toward a straight line continuous process. A sufficient number of stands are, therefore, placed in tandem to reduce the strip to finished gauge ,unless prohibited by special requirements. It is frequently necessary to anneal the strip, and then to "finish roll" in a single or two-stand mill to obtain the proper finish, degree of hardness and desired quality.

Numerous combinations of rolls are used; the most common being the two-high, four-high and cluster types. The two-high mill consists of two rolls, one above the other, both of which are motor driven through a reducing gear (Fig. 11a). The four-high mill consists of two small rolls, known as the "working rolls," backed by two larger rolls, one above and one below, both of the small rolls being driven (Fig. 2). This combination is expensive, but has a decided advantage because it is commonly known that a small roll is much more efficient in reducing and stretching than a large roll. The compression and strain is taken by the "backing-up" rolls and it is very effective in minimizing roll spring, which is especially noticed when rolling wide strip. In general, two-high mills are used for rolling strip up to 20" wide and four-high mills above that width.

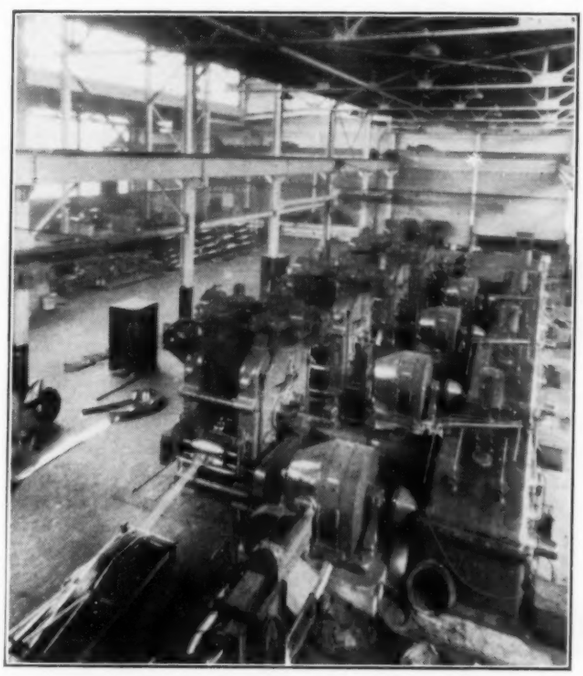

FIG. 3—General view of a cluster type tandem cold strip mill driven by four 200 h.p.—300/900 r.p.m.—250 volt motors at Sharon Steel Hoop Co., Sharon, Pa.

A cluster type mill consisting of four backing-up and two working rolls also is used. Such a mill is shown in Fig. 3.

Another point which must be borne in mind is that a mill must be readily adaptable to the rolling of a wide range of products, varying in width, gauge, and quality. In the present day very few mills are fortunate enough to have a steady market for a single kind of strip. Unless such a market is assured, it is economically unsound to build a new mill which is not fitted for diversified production; but neither should this flexibility be carried to the extreme. It would be rather absurd to put in a mill capable of the occasional rolling of forty inch wide strip, when the normal product would be strip varying in width from one inch to six inches. Likewise, there are economical limits with respect to the range in gauge. Furthermore, it is well known that the difficulties encountered in design, and likewise the cost of the mills, increase rapidly with the increase in the width of strip and the percentage reduction.

During the following discussion let us bear in mind the outstanding desired features of the finished product: *steel of accurate and uniform gauge, highly finished and polished, free from unbalanced internal strains.*

PART II

Motors

The selection of motors for driving the mill stands should be given careful consideration, but it is not particularly difficult if the rolling requirements are definitely known. The horsepower, torque, and speed range requirements depend so largely upon the mill design and the range of products to be rolled that they are usually specified by the mill builders. However, the actual types and speeds of the motors are ordinarily determined on the basis of cost and operating efficiency.

A. Mill Motors

The modern tandem mill should, without a doubt, be driven by adjustable speed d-c. motors for the following reasons:

First: The allowable rolling speed is determined by the width, gauge and required finish of the rolled strip. If a mill is to roll a wide range of products, and a constant speed drive is used, production must be sacrificed in favor of the limiting type and size of strip.

Second: Strip may often be rolled at high speeds, but it is necessary to slow down the stands for threading, because of difficulties encountered in entering the piece into the rolls. This is particularly true in the case of wide strip as it is very difficult to get the piece entered straight.

Third: Various rolling schedules require different reductions on the individual stands to obtain a particular product, and it is necessary to control the looping between stands by speed control rather than by draft.

Fourth: Where the strip is kept under tension (especially in the case of wide strip), accurate and readily adjustable speed control is essential.

The adjustable speed d-c. motor is ideally suited to the tandem mill drive since it furnishes a ready means of obtaining this desired flexibility in speed control. In addition, it is naturally a "constant horsepower motor" and the load on a cold strip mill approaches this. The narrower strips are usually rolled at the higher speeds and the torque requirements are proportionately less.

Although the stands in a tandem mill are almost invariably duplicate, the gear ratios are purposely decreased in each succeeding stand. These ratios are

based on a normal expected reduction in each stand and on using motors of the same speed range. This not only makes the motors duplicate in horsepower rating, but allows them to operate at approximately the same speed under normal conditions. Therefore, practically the whole speed range is available for adjustment of the allowable rolling speeds.

The main argument which is used against the adjustable speed d-c. motor is the fact that it requires conversion equipment which is more expensive than the step-down transformers necessary for a-c. motors. Let us consider a-c. motors briefly and see whether this slight difference in cost is offset by better operation obtained with the d-c. equipment.

Wound rotor induction motors with secondary resistance are variable speed motors, but the speed can not be easily and accurately adjusted, since the speed depends upon both the load and the secondary resistance. Speed control requires multi-point drum or magnetic controllers which are expensive and cumbersome. The speed approaches synchronism when the motor is running light and a low threading speed can not be obtained. The losses in the resistor become prohibitive if a fairly wide speed is desired.

A squirrel cage induction motor is not an adjustable speed motor and the extremely high starting torque would break the strip if it were necessary to start the mill with metal in the rolls.

A commutating adjustable speed induction motor is essentially a constant torque motor, while a cold strip mill requires essentially constant horespower. Furthermore, motors of this type, in sizes usually necessary for cold strip mills, would cost as much or more than the d-c. conversion equipment, plus the d-c. motors.

We have spoken of motors for tandem mills so far. Now, in the case of a single stand mill, we do not have to contend with loop or tension control. However, we are confronted with resistor losses if a wide speed range is desirable for different types of strip, as well as the high speed at light load. These difficulties are not serious in a great many cases, and we do find a good many single mills driven by wound rotor induction motors. An adjustable speed d-c. drive is very desirable, however, as we shall see when we come to the discussion of reel control.

The motors used in cold strip mill service do not receive the shock of suddenly applied loads that occur in most of the other main rolling mill drives and do not, therefore, require the heavy mill type construction well known to the trade. Industrial type motors are usually satisfactory, except for the larger drives where mill type construction is recommended.

A standard line of motors for cold strip mill service has been developed which meets the usual requirements. Fig. 4 illustrates a typical motor and shows very clearly the general construction. The usual accessories include speed limit switch, tachometer generator, and sometimes bearing temperature relays.

Standard insulation, which will withstand the conditions encountered in the majority of applications, is usually satisfactory. Special insulation increases the cost and should not be used unless absolutely necessary.

Although the majority of cold strip mill motors are of the open type, we have purposely chosen this photograph so as to bring out the simplicity of providing separate ventilation if desired. The air is brought from the motor pit through the coupling end and discharged at the commutator end, insuring even and thorough ventilation throughout the motor. Exactly the same construction, less the solid sheet iron enclosing cover on the coupling end, would be used for an open motor.

A cold strip mill is fairly clean and free from water, in sharp contrast to hot strip mills, since it would be impossible to obtain a highly finished product in a dirty mill.

Therefore, it is seldom necessary to force ventilate the motors with clean air merely for the purpose of keeping out dirt. However, considerable oil is used on the strip, especially in the finer gauges and finishes, and oil fumes may become a serious problem. The "pickling" machine is sometimes placed in the same building and the acid fumes may cause rapid deterioration of the insulation. Either of these difficulties may make essential forced ventilation with clean air.

Again, certain mills require such wide speed ranges, or low threading speeds, that forced ventilation is necessary to keep the motors from overheating at the lower speeds. Fig. 4 illustrated such an installation. The motors shown are rated 200 h.p., having a speed range of 300/900 r.p.m., and a threading speed of approximately 200 r.p.m. The natural fan action of the motor is insufficient to properly ventilate it at the low speed, and forced ventilation is used.

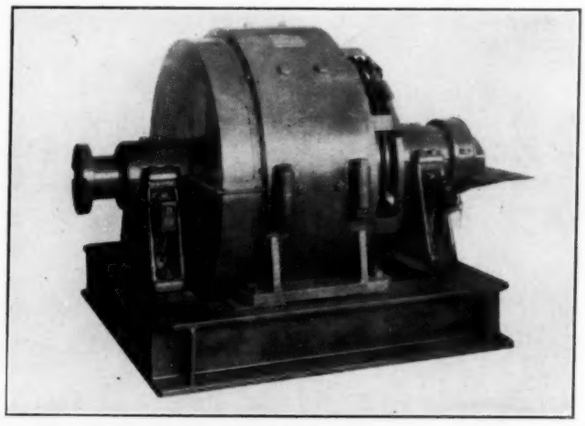

FIG. 4—A typical cold strip mill motor showing details of construction.

As previously pointed out, the speed range depends largely upon the product to be rolled. The available speed range, by field weakening, however, is limited by design considerations and economies in cost of equipment. Installations have been made, using both 3 to 1 and 4 to 1, but the great majority are 2 to 1 speed range mills. Any of the motors in the included list of standard cold strip mill motors may be built for a 3 to 1 speed range.

Most cold strip mill motors operate at 230 volts, but it may be advantageous in some cases to go to higher voltages. This is especially true where motors are fairly large. Other factors beside the cost of the particular equipment enter into such a decision however. For instance, the schedule of

production may be such that the generator could be used very advantageously for a general 250 volt relief supply during "shut-downs" of the cold strip mill.

The following is a list of the standard line motors designed especially for driving cold strip mills:

75 h.p.—400/800—230 volts
100 h.p.—400/800—230 volts
125 h.p.—400/800—230 volts
150 h.p.—400/800—230 volts
200 h.p.—400/800—230 volts
250 h.p.—400/800—230 volts
300 h.p.—400/800—230 volts

A partial list of motors for recently installed cold strip mills may prove interesting:

Sharon Steel Hoop Co., Sharon, Pa.

Type of Mill	Motor Rating	Motor Voltage
Tandem Cluster 10½"x21"	4-200 h.p.—300/900 r.p.m.	230
Tandem Cluster 8⅜"x16"	4-150 h.p.—400/1200 r.p.m.	230
Tandem 2-high 10½"x10"	3- 75 h.p.—400/1200 r.p.m.	230
Single 2-high 18"x26"	1-150 h.p.—400/1200 r.p.m.	230
Single 2-high 12"x18"	2-100 h.p.—400/1200 r.p.m.	230
Single 2-high	4- 75 h.p.—400/1200 r.p.m.	230

Acme Steel Company, Riverdale, Ill.

Type of Mill	Motor Rating	Motor Voltage
Tandem 4-high	4-500 h.p.—400/800 r.p.m.	230

Wheeling Steel Corp., Steubenville, Ohio

Type of Mill	Motor Rating	Motor Voltage
Tandem 4-high	3-500 h.p.—250/750 r.p.m.	250
Tandem 4-high	3-500 h.p.—250/750 r.p.m.	250
Single 4-high	1-500 h.p.—250/750 r.p.m.	250
Single 2-high	1-150 h.p.—250/750 r.p.m.	250

American Steel & Wire Co., Cleveland, Ohio

Type of Mill	Motor Rating	Motor Voltage
Tandem 4-high 26" face	4-400 h.p.—400/1000 r.p.m.	250
Tandem 4-high 16" face	4-250 h.p.—400/1000 r.p.m.	250

B. Reel Motors

A reel is essentially a motor driven drum, upon which the strip is wound as it leaves the final stand of the mill. (See Fig. 11 and 11a). As the winding operation progresses, the diameter of the coil increases and the motor must be slowed down correspondingly to prevent stretching or breaking the strip, since the strip is delivered at constant speed from the last stand. As a matter of fact, changes in tension during winding affect the gauge so appreciably that load regulators are used almost invariably to control the speed in such a manner that constant tension is maintained. Although a good many slip clutches have been used in the past for this purpose, they are so unsatisfactory that they are seldom used in modern installations.

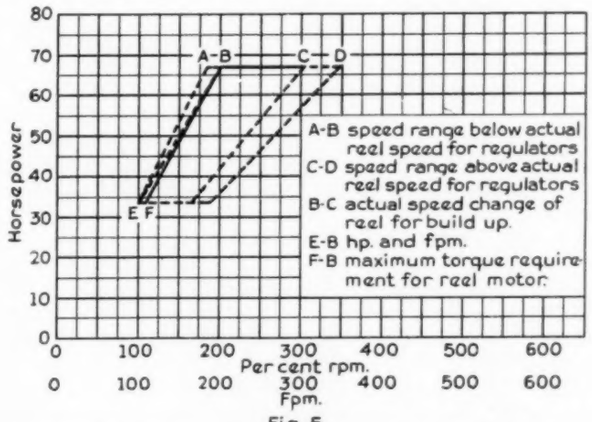

Fig. 5
Curves showing relation between horsepower and speed requirements for a reel motor due to reel build up and delivery speed.

The reel motor is always a direct current machine, since even for a constant strip speed it must have a sufficient speed range to cover the change in speed resulting from build up of the coil. Thus, if the diameter of the reel drum is 20" and that of the completely wound up coil is 30", the speed range of the motor must be at least 30 to 20 or 1.5 to 1. However, there is another point which must be considered: The regulator operates, through vibrating contacts, across a resistance in series with the reel motor field so as to maintain the proper speed, and consequently, the proper tension. When the contacts are open all of the resistance will be inserted and the motor will run at its maximum or weak field speed. On the other hand, when the contacts are closed, the motor will run at its basic or full field speed. Any intermediate speed, therefore, is determined by the ratio of "time open" to "time closed" of these vibrating contacts. It is apparent that the contact vibration must gradually slow up as the limits are approached. This characteristic, as well as the fact that the response of the motor to field changes near the limits is more sluggish, is very apt to produce "hunting", that is, overshooting first above then below the desired speed. This is especially likely to happen near the maximum speed. It is therefore very desirable to select a speed range greater than that actually required for build-up. A maximum speed of the motor 15% higher than the top speed actually required, and a minimum speed 10% lower than the reel build-up required, is usually satisfactory. For example, for a reel build-up of 1.5:1 we should choose a 2:1 motor.

If a constant tension is maintained on a strip issuing from a mill at a constant linear speed, the rate of energy is constant, i.e.,

$$\text{Feet per minute} \times \text{tension in pounds} = \text{HP} = \text{a constant}$$

$$\frac{}{33{,}000}$$

Therefore, neglecting the small difference in friction and motor losses due to the change in speed incident to reel build-up, a constant current input to the motor at a constant armature voltage will result in a constant HP output or tension on the strip. Constant input to the reel motor is maintained by a constant current regulator.

Thus far we have considered only a constant speed mill. However, it is obvious that the reel motor must have sufficient range to take care of build-up at any corresponding delivery speed for which the mill may be adjusted. Thus, if the mill were to have a delivery speed range of 2 to 1, the speed range of the reel motor would become 2 x 2 or 4 to 1 to take care of the delivery speed range, reel build-up and necessary regulator margin.

Referring to our simple formula for HP again, it will be noted that if constant tension is maintained on the strip, the HP will increase in direct proportion to the delivery speed. This would mean that the motor must be good for constant torque over the speed range required for change in delivery

speed. However, since heavy strip is rolled at slow speed, and light strip at high speed, a greater tension is usually desired at low speed than at high. The result is that usually a motor which will deliver a constant horsepower output throughout its speed range is required.

If the speed range required is so great that it is beyond the bounds of economical and good engineering design, a "variable potential" scheme of control must be used for changes in speed necessary for the varying delivery speed. This consists essentially of a generator of which the voltage is varied in proportion to the delivery speed. By using this method we automatically obtain constant torque over the speed range necessary for the varying mill speed.

From the foregoing, it is obvious that a DC adjustable speed motor is the only logical motor to use for a reel drive. An industrial type motor is usually satisfactory unless there is some very special requirement to meet.

PART III
Control

The control equipment, unfortunately, cannot be selected as simply and easily as the motors, since the intelligent application means a thorough knowledge of the products to be rolled. Frequently, this is difficult to foresee. Every new application seems to present new problems in manipulation and operation. There seems to be no single criterion for the control equipment, which may be slightly modified to meet the various special requirements. This apparent state of confusion is the result of the rapid progress in applications for rolling "Specialties". This is all the more reason for studying the details before selection is made. It is a crime to pass over them as "mere details which may be settled later," because the correct application pays big dividends in the form of labor saving and increased production. Moreover, the control determines, to a large degree, the accuracy of gauge, quality and finish of the strip. Again, the study of actual requirements often eliminates costly refinements and complications which mean, not only a saving in the initial cost of equipment and installation, but maintenance.

A. Mill Motor Control

Although there are almost innumerable refinements and modifications, there are, in reality, only two types of control—*rheostatic* or constant potential, and *adjustable potential.*

Rheostatic Control is commonly known as "magnetic control" and is shown, in elementary form, in Fig. 6. The power is supplied from a constant potential bus and the motor is started by successively cutting out resistance in series with the armature until the motor is directly across the bus and up to "basic" or full field speed. From that point the motor is accelerated by inserting resistance in series with its field until it comes to full speed or any intermediate desired point, depending upon the setting of the field rheostat. The contactors shown are magnetically operated and function automatically in the proper sequence when the desired operation is indicated by pressing the corresponding push button. This figure shows the main circuits for an individual stand but these connections are the same for each stand if used in a tandem group. It is evident that the actual acceleration of each motor is independent of the others in the group.

The **Adjustable Potential** scheme of control for a three-stand tandem mill is shown in simplified form in Fig. 7. It will be noted that the control for an individual motor is very simple compared to the constant potential equipment. The armature circuit consists essentially of a contactor and switch for disconnecting the motor from the variable potential bus. The motors are all started and accelerated together by building up the generated voltage through automatic control of the generator field. It should be noted that, in this case, the motors are accelerated with whatever field is determined by the setting of the rheostats. This is possible here because the variable potential scheme gives, in effect, a magnetic controller having an infinite number of accelerating points and provides very smooth acceleration.

It is evident that these two types of control are basically different and the first step should be to select either one or the other. Variable potential equipment is by far the most flexible, simple and satisfactory for tandem mills, but is not justifiable, in all cases, because of the cost of the motor generator set and its attendant switching and control apparatus. This is especially true when the drives are small and sufficient 250-volt DC power is available in a mill. However, when the drives in a tandem mill are of appreciable size, requiring in the neighborhood of 500 or 1000 KW, and it becomes necessary to increase the capacity of the conversion equipment, there should be no question as to which control should be selected. Sets of the above size are very frequently used for the general mill supply, and the switching can be easily arranged so that they can be used as relief generators on the mill circuit, if desirable, when the tandem mills are not operating.

If variable potential control is not justifiable on the above basis, the question arises as to when it should be selected in spite of the cost. This depends on the kind of strip to be rolled, and the necessary threading speeds.

Let us divide the innumerable types and kinds of strip into two general classes:

Class I: Heavy gauge—will stand considerable jerking and stretching without affecting the gauge appreciably. Narrow strip—does not require tension between stands to eliminate wrinkles.

Class II: Light gauge—will not stand jerking or stretching without affecting the gauge, and tension between stands is necessary to eliminate wrinkles. Wide strip—invariably requires tension between stands to straighten wrinkles.

In general, magnetic control is satisfactory for rolling Class I, and variable potential control is essential for rolling Class II. This is probably apparent from the fundamental differences we have already noted between these two types of control. Some further points may be interesting however.

The magnetic control is so laid out that a slight time delay is obtained between the starting of each successive stand so as to form a loop between the stands. The stop push buttons and protective devices are so connected that all stands in a tandem group are disconnected from the line and stopped simultaneously when any one of these devices functions. Of course the differences in friction load,

draft, dynamic braking and so forth determine whether the drives actually stop together or not. If it is necessary to stop the mill with strip in the

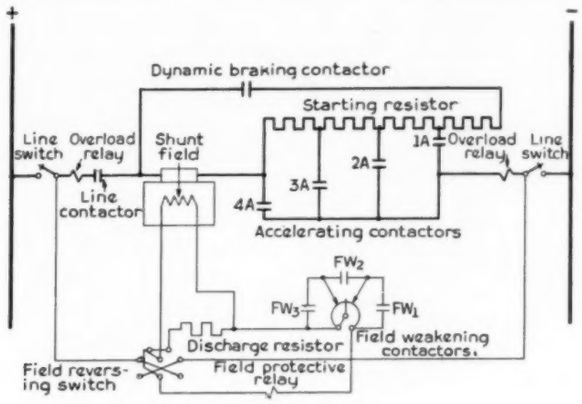

Fig. 6
Elementary control diagram
Showing usual magnetic or constant potential control scheme
For a cold strip mill stand motor

rolls, this looping between stands protects the strip from undue strain. It also prevents breaking the strip while starting because it is impossible to adjust separate magnetic controllers to accelerate with exactly the same characteristic. Even though this could be approximated for one rolling schedule, a complete readjustment would have to be made for another schedule, and this is out of reason. If tension is desired it must be obtained, after the mill is threaded and running, by speeding up each succeeding motor to take up the slack. This can be done very smoothly by vernier adjusting rheostats, but this means they must be manipulated each time the mill is threaded. This is a laborious task, however, and push button controlled contactors are usually employed for inserting a small amount of resistance in series with the motor field for this speed up operation. Of course, this is not quite as smooth and it is difficult to keep from stretching the strip now and then. These variations in tension during de-

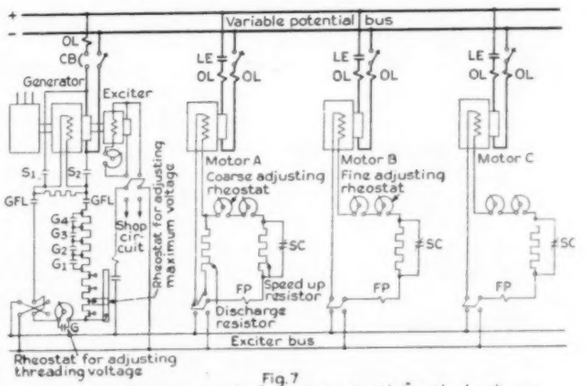

Fig. 7
Elementary diagram showing variable potential control scheme
for a three stand tandem cold strip mill

celeration or acceleration, as well as the difficulty of getting the strip under tension, make magnetic control unsatisfactory for rolling Class II strip.

Reduced speeds for threading the strip into the rolls is often desirable, as pointed out previously. For threading at or near basic speed with magnetic control, a scheme is used such as that shown in Fig. 7. (Disregard the dotted knife switches and connections between armatures at present). The only difference, in the main connections, between this and the ordinary magnetic control is the additional rheostat in each motor field circuit. These rheostats permit adjusting the threading speeds of the motors to the proper relative values when the field weakening contactors short circuit the main rheostats. These field weakening contactors close when the "Thread" button is pressed. After the strip is threaded into the mill, the "Run" button is pressed and the field weakening contactors open in sequence so as to accelerate each drive smoothly and approximately maintain the loop obtained while threading. It is evident that this is satisfactory for Class I, but not for Class II strip.

We have shown when we could and could not use magnetic control. Now let us see if adjustable potential control meets the requirements in these negative cases.

We have already pointed out that, with an adjustable potential scheme of control, the motor field rheostats are adjusted for the desired running speed and remain at this setting, in the motor field circuit, during acceleration and deceleration. Under these conditions extremely smooth starting and stopping is obtained, and the speeds of the drives are always in the correct ratio. If Fig. 7 is again referred to, it will be noted that the control for the field circuit of the generator can be arranged to obtain the following operation. The generator field rheostat can be adjusted for any desired threading speed, to which all drives will decelerate together, when the "Thread" button is pressed. When the "Run" button is pressed, the entire field rheostat will be short circuited in successive steps, bring the generator up to full voltage and the drives up to the speeds for which their rheostats are adjusted. When the "Stop" button is pressed, the entire resistance of the rheostat will be inserted in the field of the generator in successive steps. This will bring the generator voltage to zero and stop all of the drives simultaneously. Surely this type of control is ideally suited for rolling Class II or for very low threading speeds.

It is interesting to note that threading difficulties seem to increase in proportion to the increase in width as well as to the decrease in gauge. This throws the strip requiring very low threading speeds into Class II and our general statement in regard to selection of control based on these two classes holds for this requirement as well.

Various magnetic control schemes have been used in an effort to obtain threading speeds below basic. One of these is shown in Fig. 8. The negative sides of the motor armatures are connected through switches, as indicated with dotted lines in this sketch. For threading, the line contactors (LE and 1A) are left closed, but the accelerating contactors are opened so as to insert all of the starting resistance in series with the armatures. Under this condition the motor armatures, as well as the resistors, are in parallel, and it is evident that the same voltage will be applied to all armatures irrespective of slight differences in the resistors. The same voltage will also be applied to all motors at the same instant during acceleration or deceleration, even though there may be slight differences in the resistor steps or timing of the accelerating con-

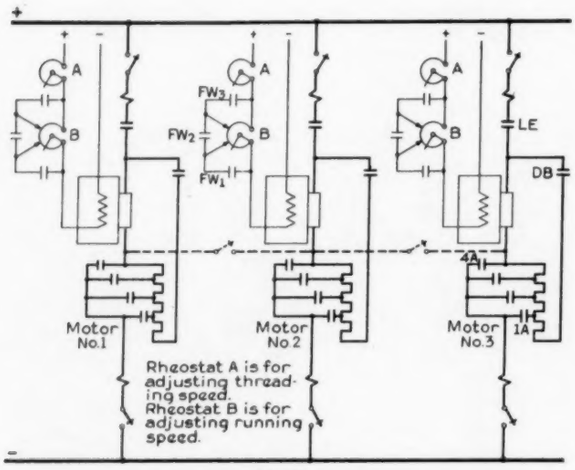

Fig. 8
Elementary diagram ("magnetic" control) showing method of obtaining "basic speed" for threading (dotted switches and connections for obtaining threading speed below basic (see text)

tactors. The motors will therefore maintain their relative speeds at all times. However, when they are running light the resistor drop is negligible and their speeds will not be reduced appreciably. Therefore, the first stand will have to be threaded at basic speed, and, although the speed of all will be reduced further as the piece enters each succeeding stand, this is not a desirable characteristic. The piece is easier to thread in each such succeeding stand because it is thinner and can be handled more readily. Accordingly, considerable time is wasted. Furthermore, resistors which will stand this severe "long-time" duty are expensive and require a great deal of space.

Another scheme, which is very similar to that just described, is to use a common resistor, with contactors for automatically inserting it in series with the bus feeding all the motors. Obviously this has the same disadvantages as the preceding scheme. In addition, the actual amount of resistance in each step is dependent upon the number of motors operating in parallel and these steps must be readjusted if one of the motors is not in service, which is frequently the case.

The scheme indicated in Fig. 8 has also been used in an attempt to maintain tension during deceleration and acceleration. To stop the mill, all of the accelerating contactors are opened, and dynamic braking applied to all motors in parallel. The motors will decelerate smoothly, but the tension held will depend upon the time constants and characteristics of the fields, as well as the relative field rheostat settings, any of which may cause excessive tension even for Class I strip. During acceleration, however, the limited number of accelerating points and varying torque requirements on each stand, make it impossible to avoid stretching the strip.

On single stand mills we are not troubled with the difficulty of keeping the strip under tension between stands and usually magnetic control is suitable for rolling either Class I or Class II with equal satisfaction. The main exception would be in the rolling of unusually wide and light gauge strip, where slight variations in tension between the reel and mill during acceleration and deceleration might affect the gauge appreciably. We will be better prepared to make our decision in regard to this after we have discussed reel control.

Variable potential control is rarely justifiable even for threading speeds below full field speed on single stand motors. A reasonably low threading speed can be obtained by using an armature-shunting resistor, and even though it is expensive it does not compare with the cost of conversion equipment.

The main connections would be the same as that shown in Fig. 6 except the dynamic braking section of resistance would be connected in parallel with the armature, and the two in series with the starting resistor. The motor will run at a reduced speed depending upon the resistor values and required t rque. Fig. 8a shows the relation between torque and speed when operating with this method.

When strip is very wide, it is difficult to get it started in the rolls straight, which is very essential

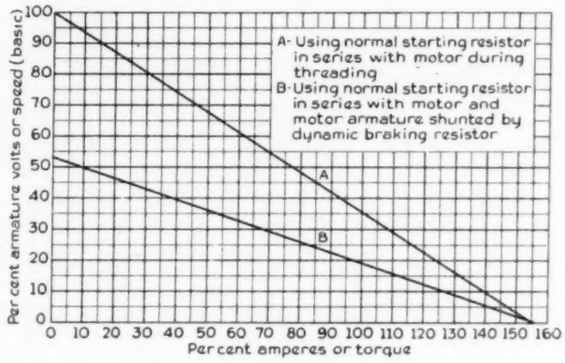
A- Using normal starting resistor in series with motor during threading
B- Using normal starting resistor in series with motor and motor armature shunted by dynamic braking resistor
A
B
Per cent armature volts or speed (basic)
Per cent amperes or torque
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160
0 10 20 30 40 50 60 70 80 90 100

Fig. 8a
Showing speed torque relations for a 500 hp. motor for threading speeds below basic obtained with "magnetic" control

because otherwise the strip tends to skew or work toward one side of the mill. In such a case it is necessary to use the shunted armature connection for threading, as just explained. The "Thread-Run" button should be replaced by the "Jog" button which should be rewired so as to close only LE, 1A and DB contactors while pressed and to open them when released. A great deal is gained in ease of operation if a "Stop-Jog" button is placed on the back of the mill where the man threading the mill can easily reach it.

Of course, the resistors are laid out for a short time rating and any armature resistance or shunted armature method for obtaining threading speeds below basic requires increased capacity of the resistors. Resistors of high capacity and long time rating are expensive, but a thorough study of the requirements often results in materially reducing the cost. Fig. 8a shows two torque-speed curves for a 500 HP motor. Curve A shows the torque-speed curve when using the starting resistor (the value of resistance is that which would normally be used for starting a motor of this size) in series with the armature. Curve B is calculated on the basis of shunting the armature with a value of resistance which would normally be used in the dynamic braking circuit for a motor of this rating. Let us assume that 70% torque is a normal requirement. From curve B we note that for 70% torque we will obtain a speed of 30% (basic) speed. Suppose 30% speed gives a linear speed of 30 FPM and the reel

were 8 feet from the mill. Surely it would not be necessary to run out more than 10 feet before the mill was stopped. This would require slightly more than 20 seconds because of time lost in acceleration. A resistor which would carry say 73.5% (3.5% passing through the shunt section) for 30 seconds would be ample. This is an approximate method, but this simple calculation might save half the cost of the resistor. Unfortunately the designer of cold strip control equipment seldom has any information in regard to the product to be rolled and naturally he plays safe and quotes a very heavy capacity resistor.

It is interesting to note the very poor speed regulation obtained by the two methods as shown in curves A and B.

The foregoing has given us some of the general characteristics of the two types of control and now a few of the operating details of each type may prove interesting.

Operating Details

Magnetic Control:

(a) **Single Stand Mills** (See Fig. 6).

Desirable Features:

A Line Switch and Line Contactors—for disconnecting both sides of the motor from the power source.

Instantaneous Overload Protection—in each side of the line is necessary for short circuits and severe overloads. As the service is of a continuous nature thermal overload protection is not essential.

A Reasonable Number of Accelerating Points—to ensure smooth acceleration (four points for motors up to 150 HP, and five points up to 500 HP have proven very satisfactory).

Dynamic Braking—to ensure a quick, smooth stop. The mills usually have very little friction and "coast" for a considerable time when stopped, unless dynamic braking is used. In the case of strip breakage, a cobble or a bad place in the steel, serious damage to rolls may be avoided if they can be stopped quickly enough. Two steps of dynamic braking are sometimes used and may become a considerable time saver in the case of a single stand where the reel tends to pull the mill in an attempt to maintain tension during stopping. This is especially true for "skin rolling" or finishing operations where the draft is very light and the material must be stopped and gauged frequently.

Intermittent Starting Duty Resistor—The service is essentially a short time starting and stopping duty with a relatively long time for cooling of the resistor and a great saving can be made in this connection. It should not be overlooked, however, that the motors must be started with metal in the rolls. The capacity must be increased if a threading speed below basic is desirable, as explained previously.

Field Reversing Switch—Occasionally it is necessary to back out a strip and provision for emergency reversing should be provided, especially for four-high mills. In a two-high mill the working rolls can be raised so as to take out the piece without reversing, but this is impossible on four-high mills since the backing up roll alone can be raised. Ordinarily it is satisfactory to obtain emergency reversing by a simple DPDT motor field switch and this is considered standard. Occasionally, however, inaccessibility of the control panel, or other peculiar conditions, make magnetic control of motor field reversing justifiable.

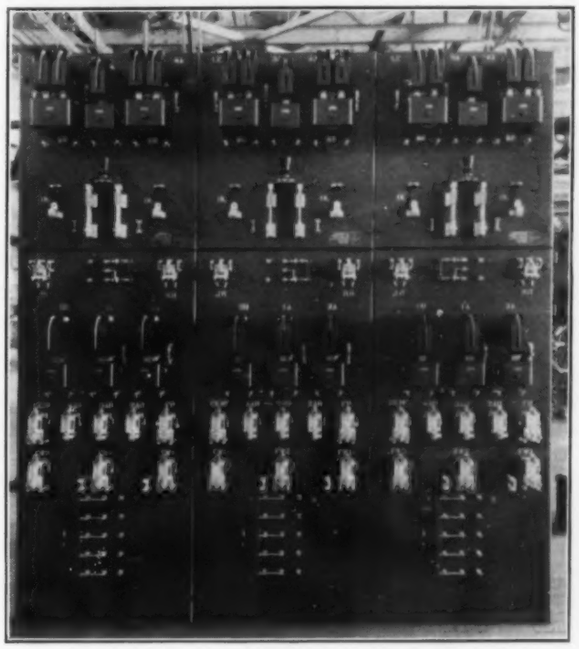

FIG. 9—Typical "magnetic" control panels for tandem cold strip mill service, Blair Strip Steel Co.

Discharge Resistor—To prevent excessive voltages on field coils when the field switch is opened.

Field Protective Relay—For stopping the equipment in case of losing the motor field.

Field Rheostat—Hand operated rheostats are recommended for motors up to 300 HP and motor operated rheostats above that rating. This is based upon the size of the rheostat and ease of operation. Other factors, such as limited space in the mill, may be the deciding factor, however. Hand operated rheostats are usually placed on the opposite side of the mill stand from the operator and controlled by a hand wheel and a long shaft (See Fig. 11).

Field Weakening Relays—The number of relays varies widely, but three points for speed ranges up to and including 3 to 1 have proven very satisfactory.

Time Limit Acceleration—In rolling the lighter strips, requiring less torque, the acceleration should be just as smooth as for heavy strips, requiring more torque. Time limit acceleration for both armature and field points is therefore very essential to satisfactory operation. The use of a field accelerating relay which is actuated by armature current is particularly objectionable since hard spots in the strip may cause the relay to function during rolling and break the strip.

Push Buttons:

Run—The operator should have a push button which will cause the motor to accelerate up to the speed determined by the field rheostat setting, and continue to run at this speed until one of the protective devices function or the "Stop" button is pressed.

Jog—He should also have a push button for ac-

celerating the motor up to basic speed when pressed and arranged so as to stop the motor when released. This is essential for threading and adjusting the piece in the rolls and for "inching" the mill over to inspect the rolls.

Stop—It goes without saying that a button for stopping the motor must be provided.

Thread-Run—This is an optional push button depending upon the desirability of a reduced threading speed. When the "Thread" button is pressed, the motor should decelerate to the threading speed for which the equipment is arranged; and when the "Run" button is pressed, the motor should accelerate to its original running speed.

Fast-Slow—For controlling the motor operated field rheostat if used.

Arrangement of Push Buttons—The push buttons should be arranged for mounting on the side of the mill housing, or on a small panel, because of the limited space available. Quite often it is found that the push buttons must be removed from the panel, and they should never be flush mounted buttons unless their exact location is known when specifying them. Related buttons, such as "Run-Jog-Stop," "Thread-Run," and "Fast-Slow" should be grouped in one station for ease of operation. A "Jog-Stop" station mounted on the back of the mill housing for the use of the operator when threading the stand is often very beneficial.

Meters—The operator should be furnished with an ammeter for use in determining the load on the motor, and a tachometer for indicating the speed of the motor or the strip. It is recommended that the tachometer be calibrated in r.p.m. of the motor because that is fixed, and the speed of the strip with respect to the r.p.m. of the motor may change from time to time due to different sizes of rolls, etc.

Tandem Stand Mills (See Figs. 6 and 8).

The same comments made for single stand mill control apply to tandem mill control with the following exceptions:

Rheostats—If the "basic" speed threading scheme shown in Fig. 8 is used, an additional fine or vernier adjusting rheostat must be used for adjusting the "basic" speeds due to various drafts. A resistance of 10% of the total is usually satisfactory for this rheostat.

Selectivity of Drives—It is frequently desirable and economical to use various combinations of operating stands in a tandem mill. In a four-stand mill the control should be so arranged that any of the following combinations may be readily and easily selected: Stands #1, #2, #3 and #4 in tandem; stands #2, #3 and #4 in tandem; stands #3 and #4 in tandem; and #4 as a single mill. The foregoing is based upon using one reel following stand #4, and it will be noted that #4 appears in all of the combinations.

Duplicate Panels—Too much emphasis cannot be placed upon the fact that the individual control equipments for a tandem mill should be duplicate of each other, irrespective of the number of stands in tandem. This simplifies wiring, installation and maintenance, as well as reduces the cost of the initial equipment and necessary spare parts. Further and far more vital, it is frequently necessary to add a stand or regroup the stands, and if the panels are duplicate the task is a very simple one. Such a scheme has been worked out and is in use at present. Fig. 9 shows three typical magnetic control panels for a three-stand tandem mill. These panels are for use with three 125 HP, 400/800 r.p.m., 230-volt motors. They are 28" wide and 90" high. Note the selector switch at the bottom of the panel for selecting the desired combination of drives. All three panels are exact duplicates in every detail, and if a four-stand mill were desired another duplicate panel would be added.

Sequence Starting—Due to the impossibility of adjusting two magnetic control equipments to accelerate two motors, with exactly the same characteristics at the same instant, it is necessary to use a slight time delay between the starting of one motor and a succeeding motor. Therefore, the equipment should be so arranged that the first motor in the group starts first, then after a short time (which should be adjustable so as to control the loop) the second motor starts, and so on to the last stand in the group.

Push Buttons:

Run—The control should be so arranged that the operator can start the mill by pressing the "Run" button on any stand. Of course, the first stand should start, followed by the other stands in sequence. This makes the operation of the mill extremely simple, and saves the operator many steps. Furthermore, it is impossible for him to make a mistake in pressing the wrong "Run" button.

Jog—If the strip breaks between any two stands, it is desirable to run the piece out of the stands following the "break", and to allow the preceding stands to remain stationary until the mill is cleared. This is the operation which should be obtained with the "Jog" button.

Stop—The control should be so arranged that all of the stands will be stopped simultaneously if any of the "Stop" buttons are pressed.

Thread-Run — All drives should decelerate to "basic" (adjusted by rheostat A shown in Fig. 8) when the "Thread" button is pressed, and should accelerate in sequence to the original speed, determined by the setting of rheostat B shown in Fig. 11.

Protective Devices — The equipment should be provided with the same protective devices as explained for single mill, but they should function so as to stop the entire mill in the same manner as the stop buttons.

Adjustable Potential Control:

(a) **Main Motor** (See Fig. 7).

Desirable Features:

A Line Switch in the negative side and a **Line Contactor** in the positive side—for disconnecting the motor from the variable potential bus. The variable potential bus is an isolated bus carrying the tandem mill motors only and double protection is obtained through the air circuit breaker for the generator.

Instantaneous Overload Protection—in each side of the line for proptection against short circuits and severe overloads. If one stand motor trips off the bus due to an overload, it is practically impossible to trip the other breakers at exactly the same instant and prevent breaking the strip. Furthermore, no

dynamic braking contactors and resistors are used on this type of mill and the motors would take considerable time to come to rest. The quickest way to stop the mill is to leave the motors connected to the generator and lower its voltage rapidly, allowing the motors to pump back into it. Therefore one of the overload relays (OL1) on each motor is set to trip on a normally severe overload, but instead of tripping the motor off the line, it functions so as to automatically reduce the generated voltage to zero causing all motors to decelerate and stop together. This frequently prevents breaking the strip. The other relay (OL2) for each motor is set to trip at excessive overloads, such as short circuits, and it functions so as to trip the particular motor off the bus. This is of course an emergency condition and it is desirable to clear the trouble as quickly as possible at the sacrifice of a cobble or even damage to the rolls.

Field Switch—for disconnecting the motor field from the exciter bus. Reversing is not required for backing out a strip because the field of the generator can be reversed and all motors will be reversed together.

Discharge Resistor—To prevent excessive voltages on field coils when the field switch is opened.

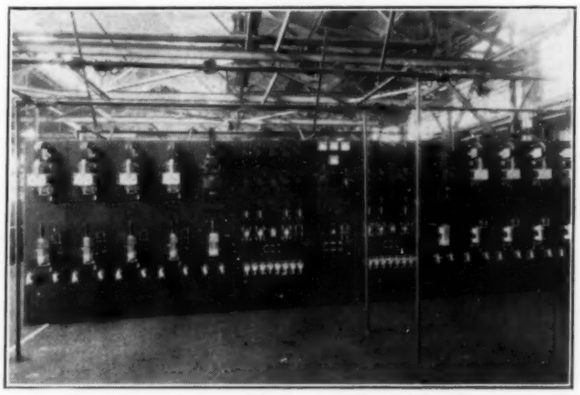

FIG. 10—Typical "variable potential" control panels for two 4-stand cold strip mill motors, two generators, and one exciter, American Steel and Wire Co., Cleveland, Ohio.

Field Protective Relay—for tripping the line contactor of any motor which loses its field. This is an emergency condition of the same nature as the tripping of OL2 (short circuit).

Speed Limit Switch—should be provided on the motor for tripping it off the bus in case of overspeed which is also an emergency condition.

Field Rheostats:

1. **Coarse Adjusting**—for setting the approximate desired speeds. These rheostats are almost invariably motor operated due to the size and ease of operation, although the same general comments made in discussing this feature for magnetic control apply here equally well.
2. **Fine Adjusting**—for accurately setting the desired speeds. These rheostats are especially needed in placing the strip under tension. They are preferably hand operated because they are relatively small and an indicating dial can be used to warn the operator when he is approaching the limits of the rheostat. If space or mounting difficulties prohibit its use, a motor operated rheostat may be used, but selsyn indicators or indicating lights showing the approximate position should be furnished for the mill operator.
3. **Speed-Up Resistor**—a permanent resistor with taps for adjustment should be placed in series with the field of the motor and a normally closed contactor (SC) connected across it. When this contactor opens, the resistance will be inserted in the field and the motor will speed up slightly. This is used for taking up the slack incident to threading.

Push Buttons:

The following push buttons should be provided for mounting on the mill housing of each stand for controlling the motor driving the particular stand:

Close—for closing the line contactor or circuit breaker which connects the motor to the variable potential bus. An indicating light should be provided for the operator to indicate when the contactor is closed. The closing control circuits should be so arranged that it is impossible to connect a motor to the bus if the generator circuit breaker is closed or if there is a voltage across the contacts of the breaker when open. Such a voltage could be generated by the generator itself or the motors, while drifting to a stop in case the breaker is opened during rolling. It should also be impossible to close a motor breaker unless its line switch has been closed, its field is energized and the motor is practically stopped.

Open—for opening the motor line contactor and disconnecting the motor from the bus. A light should indicate to the operator when the contactor is open.

Fast-Slow—for controlling the motor operated field rheostat.

Speed-Up—for controlling the speed-up contactor (SC).

Counter e.m.f. Relay—for protection against closing the line contactor until the motor is practically at a standstill.

(b) **Generator** (See Fig. 7).

Desirable Features:

A Line Circuit Breaker—for disconnecting the positive side of the generator from the bus and a **Line Switch** for disconnecting the negative side.

Instantaneous Overload—for protection against excessive overloads on the generator.

Field Reversing Switch—for reversing the generator field and thereby its armature voltage, making it possible to reverse all motors together in order to back out a strip. Although, this is inherently an emergency condition, reversing by magnetically operated contactors is sometimes justifiable, as explained before.

Discharge Resistor—for protection against excessive voltages when the field circuit is broken.

Field Rheostats:

1. **"Threading" Rheostat**—for adjusting the "threading voltage" and thereby the speed to a satisfactory value for entering the piece into the rolls. This is usually a very low speed, and once adjusted, it is rarely changed. This rheostat may,

therefore, be a hand operated rheostat and located in the control house if it is difficult to mount it in the mill. If a very wide range in threading speed range is desirable for some special condition and the rheostat attains considerable size, however, it may become advisable to use a motor operated rheostat.

2. **Main Adjusting Rheostat**—for adjusting the maximum or "running" voltage. This rheostat is usually motor operated.

After the adjustments of tension and draft are accomplished at threading speed, the entire mill is accelerated to a speed corresponding to the "running voltage".

Push Buttons:

Open-Close—for opening and closing the generator air circuit breaker. Indicating lights should be used in connection with these buttons for the benefit of the mill operator.

Fast-Slow—for controlling the main field rheostat to adjust the "running voltage".

Thread—for obtaining the threading voltage or mill motor speed.

Run—for obtaining the maximum desired running speed.

Stop—for decreasing the generator voltage to zero or a very low value so as to decelerate the entire mill simultaneously.

Zero Voltage—The control should be so arranged; that the generator voltage may be reduced to zero to prevent creeping when the mill motors are stopped.

Meters:

An Ammeter should be mounted on the control board to indicate the total load on the generator.

A Voltmeter should be mounted on the control board and a duplicate one in the mill for indicating the generator voltage.

(c) **Exciter** (See Fig. 7).

Suitable Control—consisting essentially of a contactor and push button with indicating lamps for disconnecting the exciter from the excitation bus, a line switch, a field rheostat, a voltmeter and an ammeter. It is very desirable to use a double throw line switch for transferring the excitation bus from the exciter to the 250 DC "shop" circuit in cases of emergency.

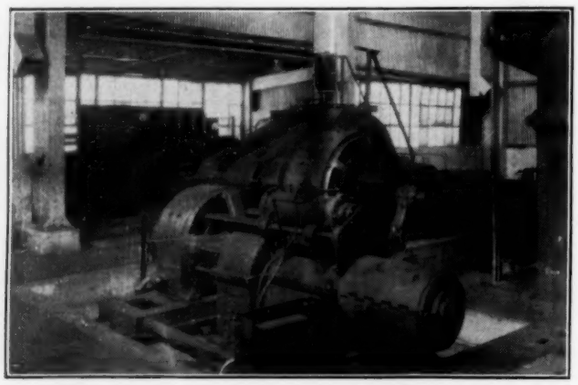

FIG. 11—General view of the last stand motor, reel and reel motor for a cold strip mill at Central Alloy Steel Corporation, Massillon, Ohio.

A typical adjustable potential control board is shown in Fig. 10. This board is used for controlling two tandem mills each consisting of four stands. The exciter panel is located in the center, a generator field control panel on either side, then the generator line panel and the four mill motor line panels on either side. It may be interesting to know the rating of the various machines. One of the tandem mills are driven by four 400 HP, 250/1000 RPM, 250-volt motors supplied with power from a 1000 KW generator, and the other, was driven by four 250 HP, 250/1000 RPM, 250-volt motors supplied from a 750 KW generator.

B. Reel Motor Control

The purpose of the reel, general operation and the reason for constant tension have already been explained in our discussion of reel motors.

Types of Reels:

1. The simplest type of reel is merely a motor driven drum with jaws, which are mechanically operated by a bar or wrench, for engaging the end of the strip. The reel drum is expanded by the same operation that locks the jaws, and collapses when the jaws are unlocked, after the reeling operation is completed. This feature makes it possible to remove the tightly wound coil by means of a hydraulically or air operated ram. Such a reel is shown in Fig. 11, in the position for receiving the next strip.

This collapsible drum is a feature necessary to all reels, but the method of expansion and other details vary.

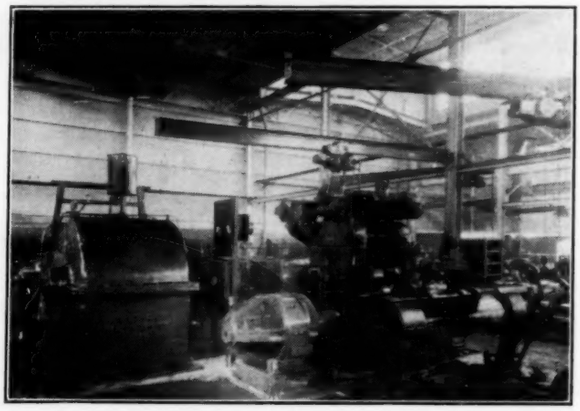

FIG. 11-A—General view of a single stand cold strip mill and reel at Sharon Steel Hoop Co., Sharon, Pa.

2. The more comprehensive reel, which is used most extensively at the present time, is one on which the jaws are automatically locked and the drum is automatically expanded. The drum is not fastened rigidly to the driving shaft, but is connected by toggles. These toggles are so arranged that the jaws will lock and the drum will expand when the drum is held back and the driving shaft is rotated. A band brake, operated by a foot pedal, is therefore used on the drum for restraining it until the slack on the strip is taken up, the strip itself furnishing the restraining force. As soon as the end of the piece leaves the mill, the restraining force disappears, causing the drum to collapse and the jaws to unlock. It is evident that, with this type of reel, tension on the strip must be maintained at all times after the

reeling operation is once started and until the coil is completed. Otherwise the drum will collapse and when tension returns the strip will pull the coil tight on the collapsed drum before it can apply the required restraining force. This makes it impossible to push the coil off and the reel must be reversed to unwind or loosen up the strip enough to remove the coil.

3. Another type of reel is that which employs a clutch between the motor and the reel. The motor is allowed to run continuously at a speed corresponding to slightly above the delivery speed of the mill. To thread the reel, the clutch is disengaged and the reel is stopped. After the reel is threaded the clutch is engaged and the reel comes up to the speed of the motor. A band brake may be used on the drum to slow it down quickly.

4. As explained previously, a slip clutch has been used between the motor and the reel in an attempt to maintain tension. It has not proven very satisfactory, however, especially on the lighter gauges, since it is practically impossible to obtain a constant force through any friction means. Furthermore, it is extremely difficult to design a slip clutch which will give the high tensions required in modern rolling. An adjustable speed motor employing a constant tension regulator has so many advantages over the slip clutch that for this type of service, the slip clutch is rarely used on modern reels.

Threading the Reel:

There are two methods of threading or starting the winding operation and the control is usually arranged so that either method may be employed. However, the control may often be simplified if it is definitely known that only one method will be used.

1. **"On the Fly"**

This method consists simply of allowing the mill to run while the reel is being threaded. The operator catches the end of the strip as it leaves the mill, walks up to reel, inserts it in the reel jaws, steps on the foot pedal, which applies the band brake, and at the same time starts the reel through a limit switch connected to the pedal. In order to take up the slack strip, the reel must accelerate to a speed slightly above the delivery speed of the mill. It is very desirable to take up the slack as soon as possible so there will be no loose wraps on the reel drum. The first few turns, if allowed to be loose, are very apt to bind and to wrinkle when the strip comes under tension, making an uneven coil. This is especially true on thin strip.

Of course, the regulator cannot function to hold tension until the slack is taken up. It will however, limit the accelerating peaks by strengthening the reel motor field during acceleration. Therefore, in order to get the reel up to speed as quickly as possible, the regulator should either be taken out of service, or set to operate at a higher value of armature current until the strip is under tension. Furthermore, if the reel is set to run at a higher speed than the delivery speed, it is evident that a means must be provided to slow it down just before the slack is taken out to prevent snapping the strip. A foot operated push button for this purpose is usually placed where the operator can reach it easily while standing on the foot pedal.

This method is employed when the strip is narrow and of such gauge that it can be handled easily. It is essential to get the strip straight in the jaws, for otherwise it tends to wrap tight on one side and loose on the other, causing wrinkles and a tension which is not uniform across the strip. Of course the difficulties in threading will depend largely upon the threading speed. Thus on a "variable potential" controlled mill having a very slow threading speed, almost any strip may be threaded on the fly because the operator has plenty of time to adjust the end of the strip in the reel jaws before starting the reel. This method is especially desirable on tandem mills because the minimum amount of time lost in threading means increased production.

2. **"From Standstill"**

This method consists essentially of threading through the mill a piece long enough to reach the reel, stopping the mill, engaging the end of the strip in the reel, starting the reel, allowing it to take up the slack and stall, and then accelerating both mill and reel simultaneously up to the running speed. In taking up the slack and stalling, the reel should run at a very slow speed, for otherwise, its inertia will very probably snap or stretch the strip. In starting the mill and reel together, it is essential to have a means of setting the regulator to hold a higher value of current input to the reel because of the additional current necessary for accelerating. This should be taken care of automatically of course, and arranged so the regulator will hold the normal current for the proper tension after the period of acceleration is completed. This method of threading is frequently used in "skin" or "finish" rolling on single stands, when rolling Class II strip. As explained previously, however, its use depends upon the threading speed of the mill and the difficulties involved in threading.

Methods of Control:

We shall limit our discussion of control mainly to that required for the reel which is used most extensively, i.e., the automatic collapsible reel discussed in paragraph #2 under "Types of Reels".

The various methods of reel motor control which will be discussed are as follows:

1. Control for reel motor covering entire speed range by motor field adjustment.
   (a) Reel following magnetically controlled mill
   (b) Reel following adjustable potential controlled mill.
2. Control for reel motor covering speed range by combination of motor field and armature voltage adjustment.
   (a) Reel following magnetically controlled mill.
   (b) Reel following adjustable potential controlled mill.

1(a). Following a magnetically controlled mill: This type of reel control is shown in elementary form in Fig. 12. The magnetic control for the mill motor (driving the last stand, if the reel follows a tandem mill) is shown also because it is necessary to consider the operation of both mill and reel motors if we are to maintain tension at all times. The reel equipment consists essentially of a magnetic controller similar to that described for the main mill motor and a constant current regulator. On observing the connections closely, however, it will be noted that a permanent resistor is used in series with the

reel motor armature, a stalling resistor is used with the reel motor, the field weakening contactors are arranged slightly differently, and that the rheostats for the reel motor and mill motor are mechanically connected. The functions of the foregoing will become apparent as we discuss the operation.

The motor is connected to the positive bus through a line contactor, and to the negative bus either through the stalling resistor (A-B) or through the bus connection (A-C) and the mill motor starting resistor or the accelerating contactors (1A, 2A, 3A and 4A).

Now suppose the reel is being threaded "on the fly". As explained previously, the mill motor will be running; the strip is threaded through the mill and reaches the reel, the reel motor is started through its own magnetic control. If the mill motor is running at basic speed, negative power for the reel will be fed through the bus connection (A-C) and the final mill accelerating contactor (4A). If the mill is running at a speed below basic, power will be fed through the bus connection (A-C), the starting resistor and the first accelerating contactor (1A) for the mill motor. The reel will accelerate and the strip will be placed under tension, as already explained. The speed to which the reel will accelerate is automatically adjusted when the mill motor speed is adjusted, because the two rheostats are mechanically connected. Slow-down to prevent snapping the strip is obtained by closing contactor FW1 which is controlled by a foot operated push button.

As soon as the strip is placed under tension, the regulator functions so as to maintain constant input current to the motor, and thereby constant tension on the strip. The operating coil of the regulator and a tension adjusting rheostat are connected in series across a permanent resistance in series with the reel motor armature. Therefore for any one setting of the tension adjusting rheostat the current through the regulator coil will be proportional to the armature current. When this current tends to exceed the desired value, the regulator contacts close short circuiting the rheostat in series with the motor field,

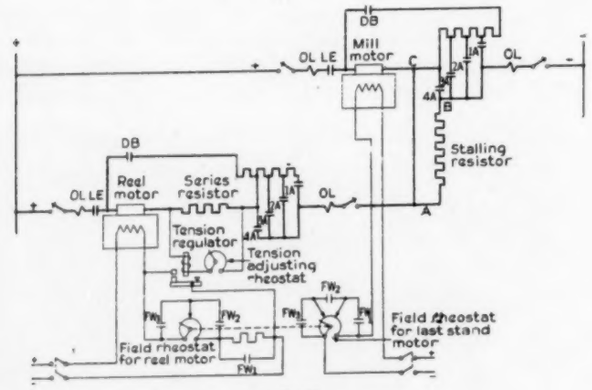

Fig. 12
Elementary diagram
Showing magnetic mill and reel control scheme

causing the motor to slow down and decrease its load current. When the current falls, however, the contacts will open so as to speed up the reel motor and again increase its load current. Thus, the contacts will vibrate to maintain the desired current in the operating coil and a corresponding load on the motor or tension on the strip.

It has been previously shown that the current input to the motor must be increased as the delivery speed of the mill is increased, if a constant tension is to be maintained on the strip. As a rule, the rolling speed is the same for any particular kind of strip, and the same kind of strip is usually rolled over comparatively long periods of time. Furthermore, the operator judges the tension actually being held more by the gauge and the feel of the strip than by the ammeter reading current input to the reel motor. The readjustment of tension can be made an automatic function rather simply, however. Another dial is mechanically connected to the same rheostat which is used for adjusting the mill speed. This dial merely consists of a number of buttons, each of which is connected to a tap on the resistor which is in series with the reel motor. The regulator coil and tension adjusting rheostat are connected to the moving contact arm so that the actual resistance, across which the regulator coil is connected, is decreased as the rheostat is moved in a direction to speed up the mill. Therefore the drop across the resistor and likewise the current in the regulator coil will tend to decrease, but the regulator will immediately function so as to maintain the normal current in its coil. The only way the regulator can do this is to weaken the motor field and thereby increase the armature current sufficiently to obtain the original drop across the resistor.

If it is necessary to stop the mill during rolling, the "Stop" button for the mill motor is pressed, but nothing whatever is done to the reel control. The mill motor will be disconnected from the line, and dynamic braking will be applied to bring it quickly to rest.

Power is supplied to the reel, however, through the stalling resistor, which is sufficient to limit the current to a safe value when the reel is actually stalled. It is evident that the power circuit for the reel is never broken, even for a fraction of a second, and tension is maintained on the strip during deceleration and when stopped. Short circuiting switches are frequently used in connection with the stalling resistor for easy adjusting of the stalled tension. Magnetic contactors may even be justifiable if the control board is rather inaccessible.

If the reel and mill are to be started from the stalled position, just described, it is merely necessary to press the "start" button for the mill. As soon as the line contactor (LE) for the mill motor closes, it will be noted that the positive sides of the armatures are connected through the positive bus. The negative sides of the armatures are connected through a bus (A-C). Thus the armatures of the mill and reel motors are connected in parallel, and when the accelerating contactors for the mill motor close, the same voltage will be applied to both armatures at the same instant. The motors will therefore accelerate exactly in step.

If the reel is **threaded "from standstill"**: The reel motor control is in its de-energized position, as shown, and the reel motor is disconnected from its power supply (LE, 1A, 2A, 3A, and 4A will be open). The mill motor is started through its own magnetic control, and enough strip run through the mill to reach the reel. Then the mill motor is stopped.

The strip is then engaged in the reel jaws and the reel started through its magnetic control. It should take up the slack strip very slowly so as to prevent

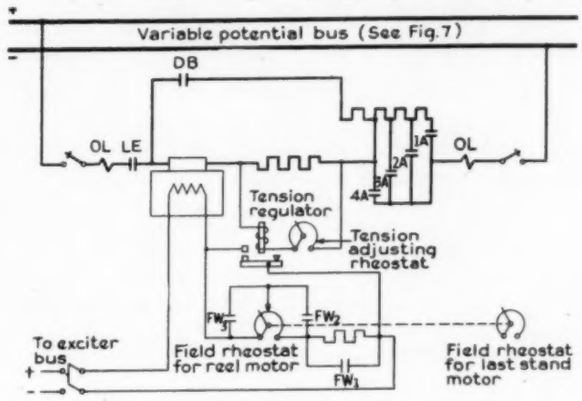

Fig. 13
Elementary diagram showing "magnetic" reel control used in connection with "variable" potential mill control

snapping, and then stall. Under this condition the reel motor receives power through the stalling resistor (A-B). This allows the reel motor to stall, placing the strip under the tension determined by the amount of stalling resistance. Thus when the "Start" or "Run" button for the mill is pressed, both reel and mill will accelerate in exactly the same manner as has just been described for the starting operation after stopping during rolling.

The simplicity of the foregoing scheme, the positive maintenance of tension at all times, the flexibility of the combination due to the arrangement of having independent, as well as parallel, control of both mill and reel motors, and the ease with which either method of threading may be used, is surely apparent.

There are many other interesting details of control which cannot be overlooked. For instance:

When the end of the strip leaves the mill, it is desirable to slow the reel down to a creeping speed as quickly as possible in order to prevent the end of the strip flying about and causing injury to the operator, strip, or equipment. This is usually taken care of by a "Creep" push button which the operator presses just as the end of the piece leaves the mill. It causes the control to decelerate the reel very rapidly to a creeping speed. When the end of the piece reaches the reel drum and is in the proper position for tying, the operator steps on a foot operated "Stop" button which causes the reel motor to be disconnected from the line, and a solenoid brake to be set. The reel will then stop almost instantly.

After the coil is tied and taken off, the reel should be rotated to place the jaws in the correct position for receiving the end of the next strip. This operation is obtained by a foot operated "Jog" button, which when pressed, causes the motor to run at a slow speed; and when released, causes the motor to stop. To prevent drifting the solenoid brake should set when the motor is disconnected from the bus.

A geared limit switch may be used for automatically bringing the reel jaws to the correct position. To obtain accurate stopping by limit switch control, the motor must be brought to the same speed each time before the switch becomes operative, because the amount of "drift" varies with the speed. The only definite speed which can be used is basic speed. The reel is first stopped with the end of the piece in the correct position for tying, without regard to the position of the jaws. Frequently, this position, however, is within a quarter of a revolution of the required position for threading. If the foot operated "Jog" button is used, the reel may be jogged this quarter revolution and stopped. But if the limit switch is used, the motor does not have time to accelerate up to the required speed within this quarter revolution, and the reel must make a revolution and a quarter before stopping.

As explained previously, the reel drum sometimes fails to expand properly, making it necessary to reverse the reel motor to back off or loosen a coil. This is accomplished by reversing the field or armature through contactors controlled by push-buttons located at the mill.

1. (b). Following a variable potential controlled mill:—

This type of reel control is shown in elementary form in Fig. 13. The equipment used is the same as that for the preceding type, except for the omission of the stalling resistor. Power for the reel motor is supplied from the variable potential bus common to the mill.

The general operation is similar to that just described, but is obtained in a slightly different manner.

When the reel is threaded **"On the Fly"** the mill is running at a speed corresponding to the selected "threading voltage." The reel is started through its own magnetic control, and also runs at a speed corresponding to the "threading voltage." The slack is taken up, and the regulator assumes control in the same manner as previously described. Both reel and mill motors are then accelerated together when the "Run" button is pressed.

If it is necessary to stop the mill during rolling, the "Stop" button is pressed, which causes the generated voltage to be automatically decreased, decelerating mill and reel motors together. When the generator voltage decreases almost to zero the motor line contactors are opened, while the reel motor is left connected and allowed to stall on the residual voltage of the generator.

In starting the mill again, the "Run" button is pressed, causing the motor line contactors to close and then the generator voltage to build up to its original value. The mill and reel will accelerate together and tension will be maintained throughout.

When threading from "standstill" the reel motor is accelerated, through its own magnetic control, from the residual voltage of the generator. It is allowed to stall on this low voltage and then both mill and reel are brought up together in the same manner as after a stop during rolling.

If it is necessary to reverse the reel, it may be done by reversing the generator field.

The comments made in regard to other operating features of the first type of reel control apply equally well in this case.

2(a). Following a magnetically controlled mill:—

This scheme of control is shown in simplified form in Fig. 14. The reel motor armature receives its power from an individual generator. The field of this generator is excited by the voltage across the mill motor armature.

If the mill has a speed range of 3 to 1, the speed of the reel motor must be controlled over the same speed range by varying the generated voltage. Thus, if the field rheostat for the mill motor is adjusted for basic speed, the rheostat for the generator field should be adjusted for 33-1/3% voltage. These two rheostats are, therefore, mechanically connected and are laid out so that the generated voltage will be proportional to the speed of the mill motor when the latter is running at full voltage. During acceleration and deceleration of the mill the excitation of the generator will also be proportional to the voltage across the mill motor armature. Therefore, the generated voltage and, hence, the reel motor speed will be proportional to the mill motor speed at all times.

The field of the reel motor is controlled by a constant current regulator to maintain a constant tension during the reel build-up, just as on the magnetically controlled reel.

When threading "on the fly" the mill motor will be running and the reel motor will be connected to the generator, but the generator field will be disconnected. As soon as the strip reaches the reel, the operator will engage the end of the strip in the reel jaws and step on the foot pedal which applies the band brake and closes the field contactor. The generator voltage will build up to a value proportional to the mill motor speed causing the reel motor to accelerate to a corresponding speed. In order to take up the slack the generator field rheostat may be temporarily short circuited by a contactor controlled by a foot operated "Speed Up" push button. To prevent snapping the strip, a permanent resistor in the motor field is short circuited by a contactor which is controlled by a foot operated "Slow Down" push button.

If it is necessary to stop the mill during rolling, the "Stop" button for the mill is pressed and the mill will decelerate. The generated voltage will decrease in proportion to the counter-e.m.f. of the mill motor and the reel will decelerate at the same rate. When the mill motor stops, the excitation voltage for the generator will become zero, but the residual voltage of the generator can be adjusted to maintain the proper stalled tension on the reel.

When threading "from standstill" the mill motor will be stopped after enough strip to reach the reel has been run through the mill. The excitation of the reel generator will be zero, but the residual voltage is usually sufficient to start the reel motor to take up the slack. If this voltage is not sufficient, the foot operated "Jog" button may be pressed, causing the field of the generator to be transferred from the mill motor armature to the excitation bus. The reel motor is allowed to stall on the residual voltage of its generator. Mill and reel are then started in the usual manner.

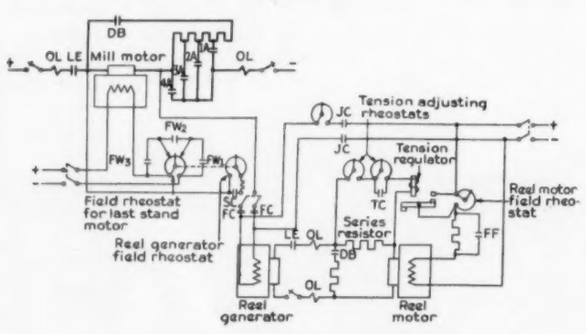

Fig.14
Elementary diagram showing "variable potential" reel control used with "magnetic" mill control

After a coil has been completed and unloaded, the reel is rotated to the correct position for receiving the next strip by the "Jog" operation just explained.

Reversing, if necessary, may be obtained by reversing the field of the generator. The excitation during this operation is taken from the exciter bus.

Although the reel motor is always left connected to the generator, except in cases of emergency, dynamic braking is desirable to slow the motor down as quickly as possible if the strip should break during an overload sufficient to cause the overload relays to function.

2(b). Following a variable potential controlled mill:

Exactly the same reel control is used as that just described (section 2a.) and exactly the same operation is obtained in the same manner. If the magnetic control for the mill motor shown in Fig. 14 were replaced by a variable potential bus and the generator field left connected across the mill motor armature, we would obtain an elementary diagram covering this type of reel control.

C. Tension Between Mill Stands

A discussion of "Motors and Control Equipment for Cold Strip Mill Drives" would be incomplete if a word were not said concerning the ever-increasing importance of tension in the strip between stands. We have previously made the broad statement that tension between stands was necessary for the rolling of Class II Strip, and have outlined the adaptability of adjustable potential control to tandem mills which require tension between stands.

A detailed consideration of this interesting subject outlining the effect of tension on the Strip, is beyond the scope of this paper. We will limit our discussion to the various methods of motor control used for maintaining tension.

The following schemes are the ones used most frequently:—

1. Motors with "drooping" speed-load characteristics.
2. Constant current regulators.
3. Idler rolls between stands—
   (a) Operating motor field rheostats.
   (b) Operating regulators.

It should be understood that maintaining a definite and accurate tension, between stands, is impossible with any scheme which depends upon the input to the mill motor for an indication of the amount of tension on the strip. This is evident when we remember that the total load on any motor will be the sum of the "rolling" power required to reduce the metal in that stand, and that required to place the strip under tension. Furthermore, the power required for tension is usually a small part of the total, and if a constant input to the motor is maintained, a relatively small change in the "rolling" power will make a considerable change in the amount of tension held. When such methods are used therefore, the tension will only be held constant as long as the "rolling" power is constant. Variations in the "rolling" power because of changes in draft or composition of the steel may be so great as to cause the

complete loss of tension or the actual breaking of the strip. Therefore, any electro-responsive means for controlling tension is at best a make-shift.

A positive method of maintaining tension must be a function of the actual tension in the strip measured by some mechanical device, such as a spring supported idler roll whose position is an indication of the tension.

With the foregoing in mind, it will be possible for us to discuss the various methods very briefly.

1. Motors with drooping speed-load characteristics

One of the simplest methods of attempting to hold tension is to use motors whose speeds will decrease with an increase in load for driving the various stands. Such a speed-load characteristic can be obtained by using a compound field winding on the motors; or by using series exciters in connection with the motors; or by inserting a small amount of permanent resistance in the armature circuit. Usually a decrease in speed of 10% to 15% from no load to full load is satisfactory. One difficulty with the compound wound motor is that the drooping speed characteristic is not constant for various speeds, but depends upon the shunt field strength. Thus a motor having 15% regulation at full speed may only have 5% regulation at basic speed. The series resistor gives a constant percentage speed regulation but occasions some power loss. The series exciter can be adjusted to give approximately constant percentage regulation.

With any of these arrangements the operation is as follows:

Referring to Fig. 1 and assuming that the mill is running the strip is placed under the proper tension by weakening the shunt field of each succeeding stand, following Stand #1. The operator judges this tension by the increase in load current on each motor and by watching the strip itself. If the load on Motor #1 increase because of a hard or thick spot in the steel, its speed will decrease, placing the strip between Stands #1 and #2 under a greater tension. This will increase the load on Motor #2 causing it to run at a slower speed. It is evident that Motor #3 will slow down in a similar manner. The action of the various stand motors may be similarly analyzed as the hard spot enters the other stands. Although this method does not maintain a constant tension on the strip, it may prevent breaking of the strip or placing it under a prohibitive strain. This depends upon the amount of compounding used as well as the gauge of the strip being rolled.

2. Constant Current Regulators

We have already discussed the method of operation of constant current regulators in connection with reel motors. They may also be used to maintain a constant input current to the motors following Motor #1. If the strip between stands is placed under tension, it is evident that the total input current for Motors #2 and #3 will be the sum of that required for actual rolling and that required for tension. If the load on the motor increases because of a hard spot, the tension will decrease between that and the preceding stand. This method therefore protects the strip, but constant tension is dependent upon the uniformity of the steel with respect to thickness and hardness.

3. Idler Rolls Between Stands

A roll is sometimes placed between stands in such a way that its position indicates the actual tension on the strip passing over it. This indication may be used to control the speed of the corresponding motor so as to maintain a constant tension by means of:

(a) Operating Motor Field Rheostats

The idler roll is so connected to the motor field rheostat that the corresponding motor will be slowed down when the tension increases, and speeded up when the tension decreases. This is somewhat of a compromise because of the mechanical difficulties and the rather slow response of the motors to small changes of the rheostat setting.

(b) Operating Regulators

Instead of operating a rheostat the idler roll may operate a regulator which controls the corresponding motor field and thereby the motor speed and tension applied to the strip. This scheme has been applied to a Steckel Cold Strip Mill for maintaining hold back tension on the strip, and has proven very satisfactory.

There are numerous modifications of the foregoing schemes, but this brief outline will give an idea of the possibilities.

It is well understood that there are many mechanical difficulties involved in using mechanical devices for maintaining accurate tension on the strip, and it is probable that we will use the compromise methods of "drooping speed" or constant input for some time. This will, no doubt, invoke considerable discussion in the future.

Lubrication and Its Application to Machine Tools

By J. H. VAN CAMPEN*

In the lubrication and its application to machine tools, the writer believes we have a wider range of conditions to contend with than most any other line of machinery used in the industrial world today. This is true from both the point of design in various types of bearings and the range of speeds under which they operate.

Therefore, we do not intend, in the brief space of this paper, to cover in detail each particular type

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of machine tool, as there are certain operating factors which determine the particular lubricant which should be used and the method under which it should be applied.

In the early days, before the development of high speed cutting steels and mass production, it was a simple matter with an oil can or a handful of grease to lubricate the crudely designed bearings. But, today, with the development of modern machine tools, there has come increased attention to the problem of correct lubrication and its application, as this is a branch of industrial economics; and machine production is directly contingent upon machine efficiency, which, in turn, is contingent upon effective prevention of wear and machine shut down by proper lubrication.

The importance of proper lubrication on highly productive machine tools, as used in the modern machine shop or manufacturing plant, cannot be over emphasized. In the majority of shops, these tools are operated by men working on a piece work of premium basis and the elimination of uncertain or haphazard lubrication by these operators is greatly to be desired.

If records were kept to show the reason for every machine tool maintenance, it would be found that much of the maintenance and repair costs could be traced to lack of proper lubrication.

In the present day machine tools, we have most generally all types of bearings in both the plain and anti-friction types operating under all forms of loadings, and in addition to bearings, there is also the problem of gear lubrication.

Correct lubrication is to be understood as the point where complete and continuous separation of the rubbing surfaces are maintained by an oil or grease film, with sufficient strength to resist the operating pressures with a minimum of fluid friction. Also, the lubricant should, as nearly as possible, be applied in the correct amount to meet the requirements of effective lubrication, and in addition, every precaution should be taken at all times to prevent the infiltration of chips, dirt, or any other foreign matter.

For the application of lubricants to machine tools, there are a great many methods among which we have the old obsolete oil hole, with its inherent ineffectiveness and wastefulness; others, as oil cups, snap oilers, ring, wick, splash, automatic and semi-automatic systems for oils, and then the grease cups, automatic and semi-automatic pressure systems for various greases.

In general, modern high production machine tools, such as lathes, boring mills, milling machines, grinders, drills and planers use for the gear and worm drives and speed boxes, an automatic oil circulating system which involves a suitable oil reservoir, either in or at the base of the machine, from which a small circulating pump forces the oil to either an overhead auxiliary tank or, by feed lines, directly to the bearings or gears to be served. The feed lines are fitted with sight feed devices and means for individual adjustment in order to regulate the flow. On the gear boxes, the oil is allowed to gather in a reservoir so the revolving parts dip, thereby carrying the oil to all wearing contacts throughout these units; from these reservoirs and bearings, overflow drains return the accumulated oil back to the main tank, where the impurities are separated by settling and the oil strained through a purifier before entering the pump again.

On the slide type of bearings for such class of machine tools as planers and boring mills, where there is no danger of chips coming in contact, the use of the one-shot system of lubrication is very advantageous, but on the ways where particles of chips are liable to come in contact, a light lubricating oil should be used for that particular purpose.

For lead screws, these should be lubricated with oil or a light grease, properly painted on with a brush.

On such class of machine tools as power presses, where speeds are medium and loads are high, sight feed oilers, grease cups, and pressure grease systems are used. Where pressure grease systems are to be used, they may be either mechanical or hand pressure type; for the use of the individual machine operator, the hand pressure type is perhaps the more suitable. In larger installations, where considerable equipment may be involved, the power lubricator will often be a time and labor saver.

Often times, the size of the machine and number of points to be lubricated will determine the type of pressure grease system to be adopted.

The trend in the past few years among the builders of machine tools has been very strongly toward the adoption of anti-friction bearings, and with the adoption of this practice, there has been given more time and study toward the problem of proper lubrication which this type of bearing demands.

Again, in lubricating the anti-friction bearing, greater care is taken in proper sealing-up or protecting the bearing against the infiltration of dirt, which also prevents leakage, which in turn is very beneficial to the lubrication problem.

The builders of modern machine tools today, we believe, are to be commended on the very efficient methods they have adopted in the application of lubricants to their product, particularly where the use of oils is involved. However, we believe that a wider adoption of automatic and semi-automatic systems could be used in the application of greases, particularly where a number of various points are to be lubricated, some of which may be in inaccessible or hazardous parts of the machine, for the operator to use ordinary methods of applying lubricants.

With the pressure grease system, which is piped to the various points, the machine can be greased while in operation, and from a safety standpoint, is especially important as it prevents any dangers from accidents to persons responsible for the lubrication.

There is one more important feature, which should not be overlooked, regarding the lubrication of any machine tools, and that is after setting up a new machine and before starting, check over the manufacturer's directions and see that all points have the proper grade and quantity of lubricant.

Also, after a machine tool has been in operation, the old oil from the circulating systems should be drained out and then refilled at regular intervals.

We believe that, in a plant where the number of

machine tools would justify, one person should be responsible for the lubrication and complete records kept on each machine.

The lubrication and its application to machine tools is a problem which deserves the closest study and attention by both the builders and users, in order to derive the maximum of efficiency and production.

Open Hearth Furnace Control

By MARTIN J. CONWAY*

It does not take a critical review of developments in the design of open hearth furnaces to show that little progress has been made since Siemen's time until comparatively recent years. Consistent with the lack of progress there has been an absence of correlated comparative performance data that would have contributed to general improvement.

Perhaps, the honor for the first real attempt to tabulate and compare the thermo-chemical and thermo-physical values of the open hearth process goes to one of our own members, Fred Clements, whose paper "British Siemens Furnace Practice" presented before the Iron and Steel Institute (London), May, 1922, may well become a work of reference for both designers and operators. In October, 1922, C. L. Kinney, Jr., and G. R. McDermott presented their very excellent paper, "The Thermal Efficiency and Heat Balance of an Open Hearth Furnace" before the American Iron and Steel Institute. Since that time until the present and especially during the past three years we have experienced a lively interest in open hearth furnace design and performance.

Much has been said and written about combustion control in the steel industry during the past few years but when we stop to consider that the fuels and air for their combustion are the most important raw materials, both in weight and value, consumed in the manufacture of heavy steel products there should be no need for an apology for attempting to add to our knowledge of the economics of the process. A common steel billet, during its manufacture from ore to steel, has had expended upon it the energy of some two tons of fuel, and twenty tons of air, much of which has been used at a pressure of 15 pounds per square inch and preheated to a temperature of from 900 to 2500 degrees Fahrenheit, has been used for combustion.

Over 200 K.W.H. have been used in driving the mills and transporting the product during its many stages of manufacture and 30 per cent of the cost of production is accounted for in heat and power requirements alone.

This cost of fuel in steel manufacture is so large in proportion to the total cost of production that efforts are being made in every direction to secure economies in fuel utilization resulting in the successful application of scientific control to the heating and melting operations.

The need for standardized methods of comparison

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OPEN HEARTH.
PROPORTIONS & PRACTICE

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
FURNACES — NUMBER	14	28	6	12	12	6	6	14	12	14	4	5	5
NOMINAL RATING - TONS	50	60	60	50	50	50	60	55	75	50	350 TILTOT	75	90
AVERAGE HEAT TONS	71	82	87	60	65	62	70	75	80	55	80	85	50
DIMENSIONS OF HEARTH - FT.	32'×14'	40'×15'-3"	40'×15'-3"	29'×19'	27'×19'-11"	36'×13'	40'×13'	32'×19'	35'×16'	29'×19'	30'×15'	30'×15'	36'×15'
AREA OF BATH SQ. FT.	448	610	610	406	403	468	600	448	550	406	460	450	450
PORTS - SIZE - INS.	40×20	36×18	39×18	38×13	42×23	36×12	36×18	NATURAL GAS	36×18	NATURAL GAS	48×21	39×18	30×19
" AREA SQ. INS.	800	648	702	494	966	432	648	" "	648	" "	1008	702	920
DISTANCE NOSE TO NOSE - FT.	36	42	42	32	29	38	44	34	38	32	34	34	34
UPTAKES & SLAG POCKETS.													
SIZE OF AIR UPTAKES - INS.	41×45	36×49	36×48	43×46	42×46	27×45	27×57	60" WELL	52×40	41×30(2)	32×63	36×48	36×36
AREA OF TWO UPTAKES SQ. INS.	3690	3528	3456	3956	3864	2430	3078	2827	4396	2520	4032	3456	2592
SIZE OF GAS UPTAKE INS.	27×30	36×37	39×38	38×46	36×42	36×36	36×40	NATURAL GAS	40×40	NATURAL GAS	45×54	36×48	36×36
AREA OF GAS UPTAKES SQ. INS.	810	1332	1482	1748	1512	1296	1440	" "	1600	" "	2430	1728	1296
AIR TO GAS UPTAKES - AREA RATIO.	4.56	2.65	2.36	2.26 STRAIGHT ACROSS	2.56 STRAIGHT ACROSS	1.87 STRAIGHT ACROSS	2.14 SET IN	" "	2.66 STRAIGHT ACROSS	" " STRAIGHT ACROSS	1.66 STRAIGHT ACROSS	2.00 SET IN	2.00 SET IN
RELATIVE POSITION GAS & AIR UPTAKES	SET IN	SET IN	STRAIGHT ACROSS					5'-0" WELL					
WALLS BETWEEN SLAG POCKETS - INS.	93	54	54	36	27	27	27	REMOVED	40	REMOVED	27	27	27
SIZE OF GAS REGENERATORS	22'-0"×7'-11"	31'-3"×7'-11"	31'-3"×7'-11"	17'-6"×10'-1"	22'-6"×8'-1"	18'-2"×8'-0"	23'-9"×8'-2"	23'-0"×9'-0"	30'-0"×18'-0"	21'-0"×7'-9"	21'-6"×7'-6"	22'-0"×9'-3"	22'-0"×9'-3"
" " AIR "	22'-0"×18'-11"	31'-3"×16'-10"	31'-3"×16'-10"	17'-6"×12'-1"	22'-6"×12'-1"	18'-2"×14'-5"	23'-9"×14'-2"	23'-0"×11'-6"	30'-0"×19'-0"	21'-0"×18'-6"	21'-0"×11'-7"	22'-0"×13'-3"	22'-0"×13'-3"
SIZE OF CHECKER BRICK	SPECIAL	10½×9½×4½	10½×9½×4½	9×4½×4½	9×4½×2½	9×4½×2½	9×4½×2½	REMOVED	13×6×2½	10½×9½×4½	9×4½×4½	9" SPECIAL	9" SPECIAL
NO/BRICK PER AIR REG. (9" EQUIV.)	4872 SPECIAL	26628	23359	13196		29102	20824			17453	17860		
" " " GAS " " "	3980	17627	18111	10752		17112	12210			12880	10279		
CU. FT. BRICK PER AIR REGENERATOR	789	1337	1226	797		1592	1109			925	997		
" " " " GAS "	564	936	955	570		907	647			682	545		
RADIATION SURFACE PER AIR REG.	7560	11248	11426	8491		11902	6212				13125		
" " " GAS "	5410	7838	9067	7025		6922	3601				7592		
ARRANGEMENT OF CHECKERS	STAGGERED	STRAIGHT	STAGGERED	STRAIGHT		PARALLEL	PARALLEL		PARALLEL	STRAIGHT	STRAIGHT	VERTICAL FLUES	VERTICAL FLUES

ST. 9-2-31.

TABLE I

OPEN HEARTH
PROPORTIONS & PRACTICE.

	1.	2.	3.	4.	5.	6.	7.	8	9.	10.	11.	12.	13.
CAPACITY & PROCESS.	50 T. BASIC	50 T. BASIC	50 T. BASIC	35 T. BASIC	50 T. BASIC	20 T. BASIC	60 T. BASIC	60 T. BASIC	20 T. BASIC	60 T. BASIC	60 T. BASIC	60 T. BASIC	35 T. BASIC
FUEL	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PROD. GAS	PRO. GAS	PROD GAS	PROD GAS
HEARTH — LENGTH & WIDTH - FT.	32' × 14'	31' × 15'	29' × 15'	24'-4" × 12'	28' × 12'-9"	20' × 10'-6	31' × 14'	39'-8" × 16'	19'-0" × 8'-6	30' × 15'	38 × 15'	43' × 16'-9"	19'-6" × 9'-10"
HEARTH — AREA - SQ. FT.	448	465	435	288	357	210	434	594	163.6	450	570	720	191.7
HEARTH — SQ. FT. PER TON RATING	8.9	9.3	8.7	8.2	7.14	10.5	8.68	9.9	16.4	7.5	9.5	12	12.78
PORTS — GAS — AREA - SQ. FT.	7.4	7.5	8.0	3.4	6.6	2.8	4.92	7.034	2.43	5.58	6.75	6.75	1.072
PORTS — GAS — SQ. FT. PER TON RATING	0.15	0.15	0.16	0.09	0.13	0.14	0.098	0.117	0.243	0.093	0.112	0.112	0.0715
PORTS — AIR — AREA - SQ. FT.	13.5	13.7	16.42	6.4	3.06	3.5	14.53	25.37	10.12			29.31	4.684
PORTS — AIR — SQ. FT. PER TON RATING	0.27	0.27	0.33	0.18	0.26	0.17	0.29	0.422	1.01			0.488	0.312
PORTS — TOTAL — AREA - SQ. FT.	20.9	21.2	24.42	9.8	12.66	6.3	19.45	32.11	12.55			36.06	5.727
PORTS — TOTAL — SQ. FT. PER TON RATING	0.41	0.42	0.49	0.27	0.393	0.315	0.389	0.54	1.25			0.6	0.385
LENGTH OF GAS PORT - BOTTOM	5'-6"	7'-6"	9'-6"	6'-9"	10'-3"	4'-6"	8'-0"	9'-0"	3'-6"			9'-0"	6'-5"
" " " " - TOP	8'-9"	11'-3"	8'-6"	2'-3"	4'-9"	3'-6"	8'-0"	6'-0"	6'-6"			5'-0"	7'-4"
CHAMBERS — GAS — CONTENTS. CU. FT.	2770	3960	2690	908	1323	708	2886	4822				3342	896
CHAMBERS — GAS — CU. FT. PER TON	55.4	79.2	52.8	23.1	26.4	35.4	57.7	80.4				55.7	59.7
CHAMBERS — AIR — CONTENTS. CU. FT.	4250	3960	3590	1099	2480	1053	4290	3507				6236	1118
CHAMBERS — AIR — CU. FT. PER TON	85.1	79.2	71.8	31.4	49.6	52.7	85.8	141.8				104.9	74.4
CHAMBERS — BOTTOM TO DOOR SILL	27'-7"	26'-5"	25'-9"	20'-7"	22'-3"	23'-2"	24'-3"	32'-6"				27'-0"	18'-10"
CHAMBERS — TOP " " "	7'-0"	7'-1"	7'-11"	6'-7"	8'-6"	7'-10"	7'-3"	8'-11"				7'-6"	7"-9"
VALVES — AIR — AREA SQ. FT.	9.60	7.06		4.9	7.6	3.07	5.94	7.06	3.12	7.06	7.06	7.06	
VALVES — AIR — SQ.FT. PER TON	0.19	0.14		0.14	0.14	0.15	0.119	0.117	0.312	0.117	0.117	0.117	
VALVES — GAS — AREA SQ. FT.	9.60	7.06		4.19	15.00	4.00	9.16	12.56	4.87	8.72	8.72	8.72	
VALVES — GAS — SQ.FT. PER TON.	0.19	0.14		0.14	0.30	0.20	0.183	0.209	0.487	0.145	0.145	0.145	
STACK — AREA SQ. FT.	20	23.7			21.5		28.27	33.18	9.62	28.27	28.27	23.75	
STACK — SQ.FT. PER TON.	160						150	180	100	153	153	162	
GROUND SPACE FURNACE & CHECKERS	46'-0" × 71'-0"	45'-6" × 77'-0"	40'-8" × 66'-0"	16'-0" × 56'-7"	52'-3" × 91'-10"	13'-9" × 36'-6"	48'-0" × 60'-9"	50'-0" × 80'-0"				51'-0" × 89'-6"	51'-0" × 20'-6"
LENGTH OF FURNACE	60'-6"	66'-5"	55'-3"	41'-8"	57'-6"	36'-5"	56'-3"	78'-6"	38'-0"			72'-0"	39'-9"
RATIO OF VALVE TO PORT - GAS	0.77	1.00		0.70	0.90	0.90	0.83	1.00	0.778	0.79	0.956	1.09	
" " " " " - AIR	1.50	1.90		1.30	0.90	0.90	1.58	2.01	2.070			2.93	
VOLUME OF CHECKER WORK CU. FT.	5466	6600	4673	1538	2577	1297	4840	7689	688	4346	4450	7415	1122
CU. FT. CHECKERS PER TON.	109.3	132.0	93.4	43.9	51.5	64.8	96.8	128.2	68.8	72.4	74.0	110.3	74.6
RATIO OF AIR PORT - GAS PORT	1.8	1.8	2.05	1.9	1.7	1.25	2.9	3.6	4.16			4.34	4.36
TOTAL PORT PER SQ. FT. HEARTH.	.046	.046	.056	.034	.03	03	.044	.054	.076			.05	.03

TABLE II

of results is obvious when attempting to evaluate the benefits to be obtained from the many control apparatus which have been developed quite recently. The difficulty in making comparison is increased because of the lack of uniformity in furnace design as shown in Tables I and II.

These data were collected some ten years ago, but, while improvements have been made, they represent the differences to be found in design today. From these data it is quite evident that furnace efficiency and practice can be considerably improved by adapting those best features of design which can be effected within the overall dimensions permitted by present fixed practice such as distance between bottom of checker chambers and charging floor level and other dimensional restrictions which cannot be changed economically.

The control of open hearth furnace operation may be considered in two separate and distinct phases. One phase of the problem is concerned with the proper regulation of fuel and air mixtures and with the maintenance of correct draft conditions in the furnace. The second phase of the problem is concerned with the maintenance of correct temperature conditions at the hearth and in the checker work.

The combustion engineer is interested mainly in the problem of obtaining the required heat input to the furnace with a minimum consumption of fuel. The operating man, on the other hand, is concerned chiefly with tonnage and in the proper regulation of furnace and checker work temperatures in order to maintain production at a peak.

Several methods of furnace control have been evolved during recent years having several or all of the following features:

Proportioning of Fuel and Air Supply.

Fuel measurement as means of air supply control.

Maintaining constant pressures of fuel and air immaterial of quantities being used.

Maintaining constant fuel and steam temperatures.

Mixing of fuels to maintain predetermined quantitative B.t.u. input.

Checker Temperature Control.

Automatic reversal through pyrometric control by time interval, predetermined high, low, or differential temperature limits and hand reversal warned by signal lights or alarms pyrometrically controlled by the limits mentioned.

Stack Draft Control.

Exit gas fan speed or stack damper.

Changing weight of stack gas by addition of atmospheric air.

These together with the usual complement of various recording and indicating instruments, such as draft gauges, pressure and temperature recorders, pyrometers, CO_2 recorders, meters, etc., go to make up the various equipment with which the plant executive can choose from and is confronted with.

Attempt to review all of the control systems of merit which are now being used would serve no useful purpose as no doubt you will learn about some of them from other speakers contributing to

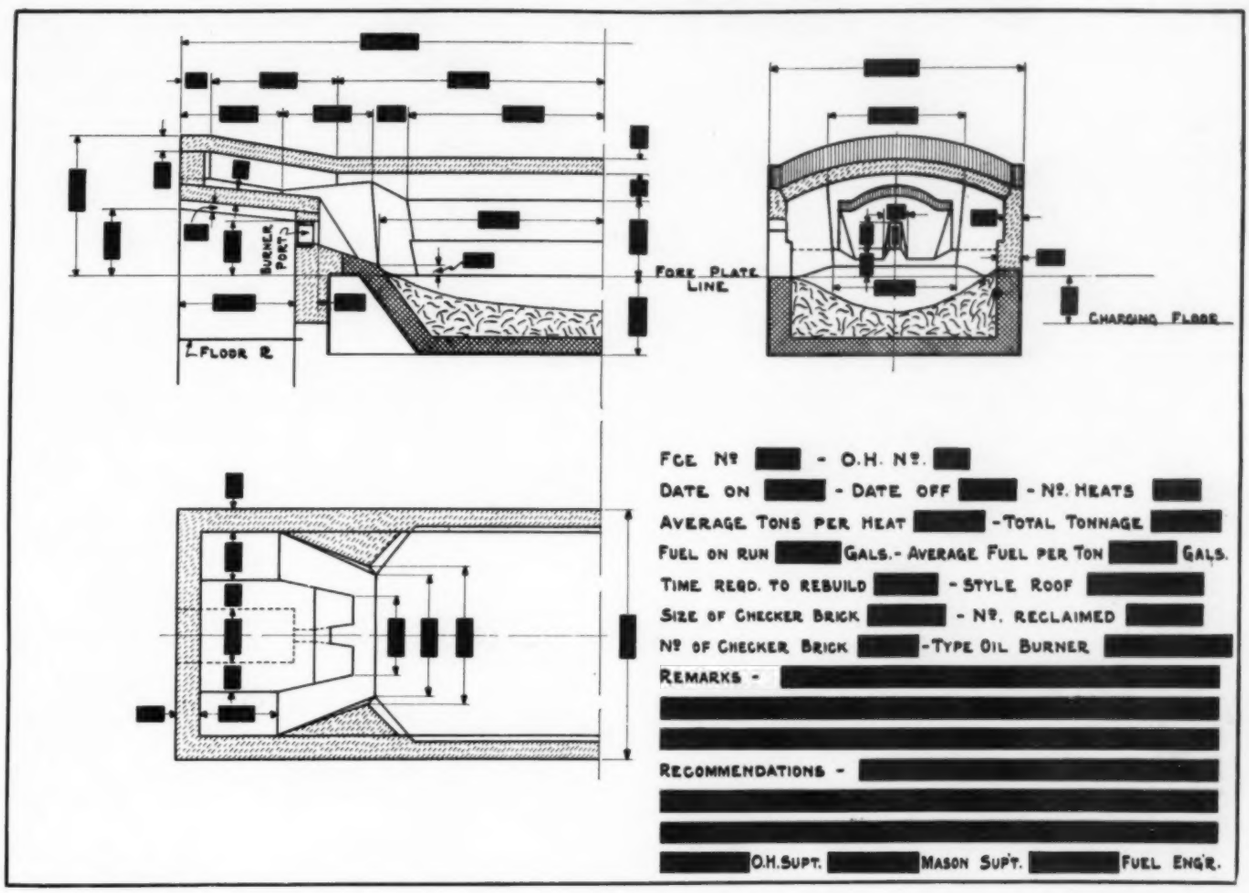

BURNER PORT
FLOOR EL
FORE PLATE LINE
CHARGING FLOOR
FCE Nº [redacted] - O.H. Nº. [redacted]
DATE ON [redacted] - DATE OFF [redacted] - Nº. HEATS [redacted]
AVERAGE TONS PER HEAT [redacted] - TOTAL TONNAGE [redacted]
FUEL ON RUN [redacted] GALS. - AVERAGE FUEL PER TON [redacted] GALS.
TIME REQD. TO REBUILD [redacted] - STYLE ROOF [redacted]
SIZE OF CHECKER BRICK [redacted] - Nº. RECLAIMED [redacted]
Nº OF CHECKER BRICK [redacted] - TYPE OIL BURNER [redacted]
REMARKS - [redacted]
RECOMMENDATIONS - [redacted]
[redacted] O.H. SUPT. [redacted] MASON SUP'T. [redacted] FUEL ENG'R.

FIG. 1.

this symposium, and the fact is that the simplest type of control will justify its use by returning in saving the cost of its installation in two years or less.

The requirements of open hearth furnace controls are approximately as follows:

1. A control of air supply that will provide a minimum excess at all rates of fuel B.t.u. input and having flexibility to provide either a reducing or oxidizing atmosphere at the will of the operator.
2. Reversal control that gives the combustion air the highest possible preheat consistent with checker design and physical characteristics of the refractory with which both the preheated air and combustion gases are in contact.
3. Stack draft control which allows a minimum amount of air infiltration, the maximum transfer of heat from the flame and gases of combustion to the bath and maintaining the necessary velocities through the slag pockets and checkers, all consistent with the design of the particular furnace so controlled.

The foregoing requirements, while apparently simple, are difficult to obtain in their entirety due to the peculiarities of the design and operation of the open hearth furnace and failure to obtain maximum results is not always due to defects in the mechanics of the particular control system but rather to faulty application. Slight dimensional changes when the furnace has been rebuilt have their effect on the accuracy of control. Such changes should be noted when comparing results obtained during two campaigns of the same furnace as a guide to future control application. A report form which the writer has found convenient for recording these changes is shown on Fig. I.

There has not been any definite formula recognized as a means of rating furnace capacities, area of and depth of furnace bath being the most favored method of rating, but as shop practice and steel analysis govern depth of bath, tons produced per furnace hour seem to be the best method of comparison of furnace performance.

With tons per furnace hour as a starting point a producer gas fired open hearth was designed with the important dimensions computed as follows: It was found from data collected that from 50 to 58 lbs. of steel is produced per square foot of effective hearth area at the metal line, and the coal consumption per ton when running at this rate is from 18 to 22 per cent. Striking an average of 54 lbs. of steel to be produced per furnace hour and that 22 per cent or 493 lbs. of coal per ton as our goal we calculated that we should have a hearth having an area of 34′ 6″ x 15′ 0″ at the fore plate, taking out the area occupied by the furnace banks and rounded corners we had left an effective hearth of 422 square feet which when multiplied by 54 pounds of steel per furnace hour, gave us a calculated production

OPEN HEARTH QUESTIONNAIRE

	SHOP NO.		
	1	2	3
FURNACES			
Number			
Nominal rating—(Gross tons Product)			
Average heat—(Gross tons Product)			
Dimensions of hearth—Feet			
Area of bath—Square feet			
PORTS			
Size—Inches			
Area—Square inches			
Distance—nose to nose—Feet			
Design			
Water cooled			
UPTAKES AND SLAG POCKETS			
Size of air uptakes—Inches			
Area of two uptakes—Square inches			
Size of gas uptake—Inches			
Area of gas uptake—Square inches			
Air to gas uptake—Area ratio			
Thickness of wall between slag pockets			
REGENERATORS			
Size of gas regenerators—Feet			
Size of air regenerators—Feet			
Size of checker brick			
Kind of checker brick			
Number of brick per air regenerator—(9″ Standard)			
Number of brick per gas regenerator—(9″ Standard)			
Cubic feet of brick per air regenerator			
Cubic feet of brick per gas regenerator			
Radiation surface per air regenerator			
Radiation surface per gas regenerator			
Double or single wall between and thickness			
VALVES			
Style of gas valve			
Style of air valve			
Size or gas valve			
Size of air valve			
Cooling water used—waste or fresh			
Style of gas regulating valve			
Square feet of bath per ton produced			
Square inch of port per ton produced			
Square inches of gas uptakes per ton produced—(One end only)			
Square inches of air uptakes per ton produced—(One end only)			
Square feet of gas checker opening—(One end)			
Square feet of air checker opening (One end)			
DOORS, FRAMES, BULKHEADS, AND BINDERS			
Style of doors			
Style of frames			
Number of doors			
Size of large doors—Inches			
Size of small doors—Inches			
Water-cooled bulkheads			
Size and type of binders			
FUEL			
Producer gas			
Natural gas			
Blast Furnace gas			
Coke oven gas			
Tar			
Oil			
Powdered coal			
Fuel pressure			
Temperature			
Style of burner or atomizer			
Has fuel pressure or temperature control			
Number of furnaces having automatic combustion control			
Type or style of control			
Number of furnaces having automatic draft control			
Are furnaces equipped with pyrometers			
Where are thermocouples located			
Are furnaces reversed by time cycle or by pyrometer control cycle			
Average time between reversals			
Regenerator temperature—high and low			
How many furnaces equipped with stack gas analyzers			
How many furnaces equipped with draft gages			
How many furnaces equipped with fuel meters			
Type and style			
How many furnaces are equipped with fans delivering air to furnace			
Rating of fan C.F.M.			
How many furnaces equipped with Waste Heat boilers			
Type and nominal Horse Power			
Horse Power produced			
Is steam or air used on fuel atomizers			
Pressure			
Temperature			
Gross tons of steel produced per furnace hour			
Fuel rate per furnace hour—high and low			
Fuel consumption per gross ton of product			
GENERAL			
Ground space—furnace and checkers			
Length of furnace			
Width of furnace			
Area of stack—Square feet			
Height of stack—Square feet			

TABLE III.

of 10.16 gross tons per hour, or 5.275 square feet of hearth area per ton of ingots.

Fuel Practice. As above outlined the basis of our calculation was 493 pounds of coal per ton of ingots.

The average analysis of the gas producer coal was:

H_2 =	5.19%
C =	76.79%
N_2 =	1.42%
O_2 =	7.96%
S =	1.83%
ASH =	6.81%
	100.00%

We found that over a long period the average producer gas analysis to be:

CO_2 =	7.30%
C_2H_4 =	0.54%
CO =	20.90%
CH_4 =	2.65%
	31.39% Containing gases.
O_2 =	0.50%
H_2 =	11.90%
N_2 =	56.21%
	100.00%

Each cu. ft. of gas contains by analysis and calculation 0.01069 lbs. of carbon so that the total gas produced per net ton of coal is $\frac{1501.75}{0.01069} = 140{,}481$ cu. ft. of gas, or, $\frac{140{,}481}{2000} = 70.24$ cu. ft. of gas per lb. of coal. The carbon content of one ton of coal was obtained by multiplying the carbon quality of the analysis and subtracting 34.05 lbs. as being lost in the ashes as determined by analysis.

The hourly furnace capacity has been determined to be 10.16 gross tons of ingots. With a fuel rate of 493 lbs. per ton of ingots, an hourly consumption of 493 x 10.16 = 5009 lbs. of coal is arrived at. Assuming round figures of 5000 lbs. of coal per hour, then, 5000 x 70.24 = 351,200 cu. ft. of gas are to be handled and will require 351,200 x 1.25 = 439,000 cu. ft. of air per hour, (includes 12% excess) for their combustion. Dividing these figures by 3600 gives as a rate of flow per second, 97.5 cu. ft. of gas and 121.87 cu. ft. of air, with an additional air infiltration to a total of 1.375 cu. ft. of air per cu. ft. of gas assumed for the outgoing waste gases, amounting to a flow of 215.48 cu. ft. of combustion products of the following analysis (by volume):

CO_2 =	14.50%
H_2O =	8.27%
O_2 =	2.49%
N_2 =	74.74%
	100.00%

or a rate of 2.21 cu. ft. of waste gases per cu. ft. of producer gas all at standard conditions (32° F. and 29.92 Hg).

A short study of these figures is sufficient to realize the importance of sound engineering advice in preference to "cut and try" methods, to ascertain the available energies and correct areas of valves, flues, checkers, uptakes, ports, etc., together with the proper velocities in these passages.

Energy Requirements: For calculating purposes, the following temperature conditions were assumed as prevailing in the different sections of the furnace:

Ingoing Air	
Entering valves	62° F.
Entering checkers	300° F.
Leaving checkers	2000° F.
In uptakes	2100° F.
Leaving ports	2200° F.
Ingoing Gas	
Leaving producers	1300° F.
Entering checkers	1000° F.
Leaving checkers	1800° F.
In uptakes	2000° F.
Leaving ports	2000° F.
Outgoing Products of Combustion	
Leaving furnace	2800° F.
Entering checkers	2500° F.
Leaving checkers	1350° F.
Entering stack	1200° F.
Leaving stack	1000° F.

The forces available under these temperature conditions within the furnace system are:

1. Buoyancy or stack effect of the air entering through the air inlet valve and being forced to the port outlet on account of being preheated.
2. Gas pressure produced by producer for the delivery of the gas from the producers to the port of the furnace.
3. Stack draft for the handling of waste gases from the outgoing port end of the furnace to the atmosphere through the stack.

Buoyancy of preheated air is fixed by furnace design and temperature of the air. In the case of the furnace referred to, the distance between the underneath surface of the rider wall arches and the bottom of the port was exactly 26 feet. A column of hot air with 1200° F. average temperature in its first 16 ft. of height and 2100° F. in the remaining 10 ft. produces a pressure of 0.161" + 0.118" = 0.279" H_2O, which was made use of in the following manner:

To produce velocity of 11.45 ft. per second for entrance of air through 54" dia. inlet	0.0296"
To overcome 90° bend from air valve into flue	0.0036"
To overcome 90° turn from regenerator neck into uptakes in slag pocket	0.0218"
To overcome friction on walls in uptakes	0.0053"
To overcome 1–45° and 1–90° turn in flow	0.0747"
To produce velocity of 56.8 ft. per second as discharged velocity through air ports	0.143"
	0.278" H_2O.

Comparison between available energy and force required shows a difference of .001" of water margin or the best possible passage design for the existing conditions.

Producer Gas Pressure: Is readily obtainable in the form of producer pressure within the limits of existing water seals. Considering that high producer pressure is usually associated with a hot and

lean producer gas, whereas, a cooler and richer gas is much preferable for efficient practice, it was considered essential to eliminate from the gas passage all unnecessary obstruction and recommend straight flue valves at the risk of occasional leakage which is less objectionable than a constant pressure loss, inherently connected with overground valves of the water cooled mushroom type.

Gas Energy Requirements

To overcome the 90° bend from the downleg of the overhead mains to the inlet valve	0.0441"
To produce velocity of 24.5 ft. per second through gas inlet valve	0.0431"
To overcome 45° turn in flow	0.0110"
To overcome friction in checkers	0.0020"
To overcome 90° turn at regenerator neck	0.0525"
To overcome friction in uptakes	0.0185"
To overcome bends in uptakes and slag pockets	0.2135"
To create discharge velocity of 105.3 ft. per sec. in port	0.4770"
	0.8617" H_2O.
or roughly a pressure of 7/8" of water.	
Due to the buoyancy by preheating in the checkers—16 feet	0.1693"
Additional column of 10 ft. to outlet of port	0.1193"
Leaving a pressure of	0.5731" H_2O.

to be supplied by the producer plus the necessary energies to deliver the gas to the starting point of our calculations—the gas main.

Waste Gas Movement: We had a combined port area of 16.24 sq. ft. available for the removal of the gases from the hearth. The energy requirements to create a velocity head of 102 ft. per second through this area 14 sq. ft. of which was assumed effective is represented in:

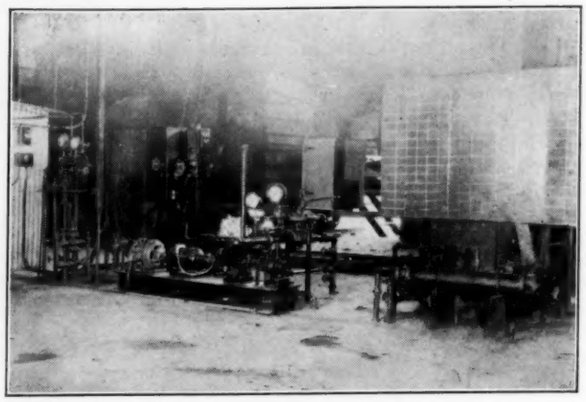
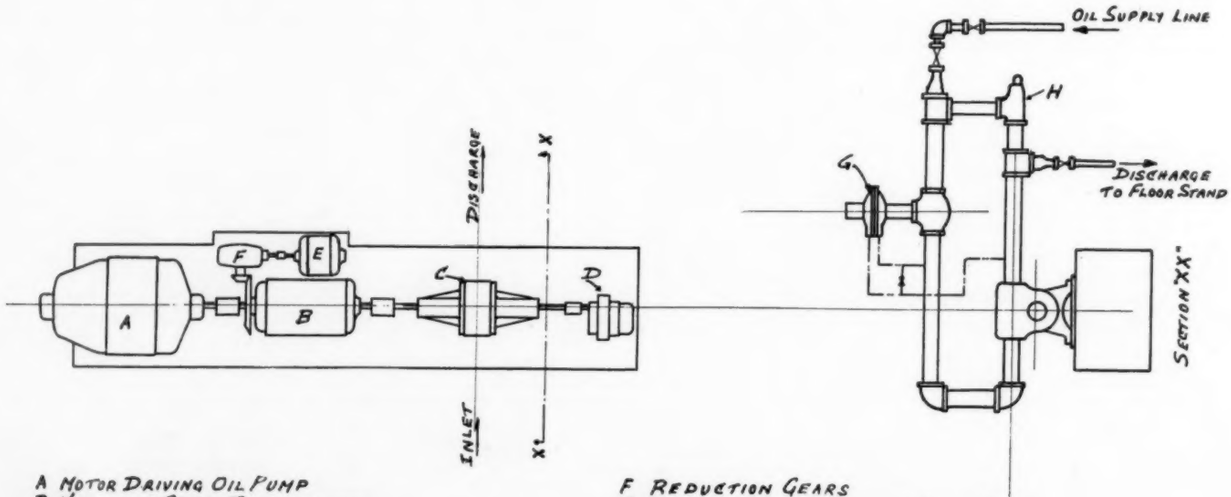


FIG. 2.

Velocity head for 102 ft. per second through ports	0.384"
To overcome stack effect of hot gas column of 10 ft.	0.1205"
To overcome bends in downtakes	0.0746"
To overcome friction in downtakes	0.0099"
To overcome 90° bend at regenerator necks	0.0454"
To overcome buoyancy of 16 ft. column of gas	0.1828"
To overcome friction in checkers	0.0149"
To create velocity of 32.2 ft. per second through reversing valves	0.0908"
To overcome friction in waste gas flues	0.0034"
To overcome 45° bend in waste gas flues	0.0041"
To overcome friction in stack flue	0.0005"
Loss due to 90° bend at base of stack	0.0720"
To overcome friction in 150 ft. stack	0.0945"
	1.0974"
The available stack draft was determined as leaving a balance of available draft over actual requirements of	1.454" .3566"



A MOTOR DRIVING OIL PUMP
B VARIABLE SPEED TRANSMISSION
C POSITIVE DISPLACEMENT PUMP
D BLOWER - SUCTION CONNECTED TO AIR CONTROLLER
E MOTOR FOR CHANGING SPEED OF "B" OPERATED BY PUSH BUTTON "N" FIG. ( )
F REDUCTION GEARS
G DIFFERENTIAL PRESSURE REGULATOR
H PRESSURE RELIEF VALVE

FIG. 3.

to be made use of to overcome addition resistance in the various passages of the furnace as the campaign progressed.

This particular furnace lived up to its performance forecast and has justified the additional effort expended in carefully checking its chief dimensions against best practice as then known.

The same beneficial results which are the outcome of co-operative thought between the operating, engineering, and service departmental heads when redesigning and rebuilding furnaces can be extended beyond the confines of any one particular plant and benefit the industry as a whole and I suggest that our Association take the lead through its Combustion Engineering Division by collecting these furnace data making the resumé available to the participating companies. A suggestion in the form of questionnaire is shown in Table III. This questionnaire may not be complete, but it would at least be

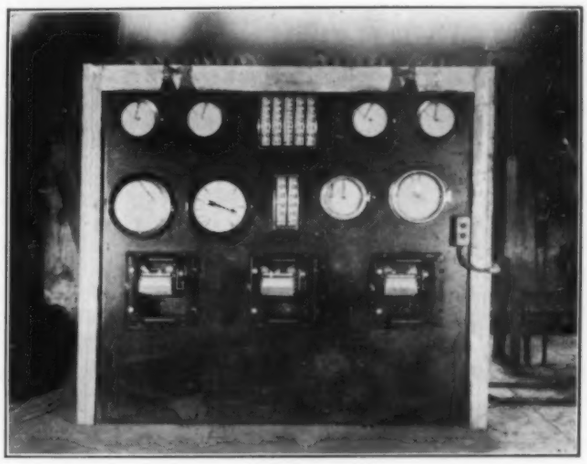
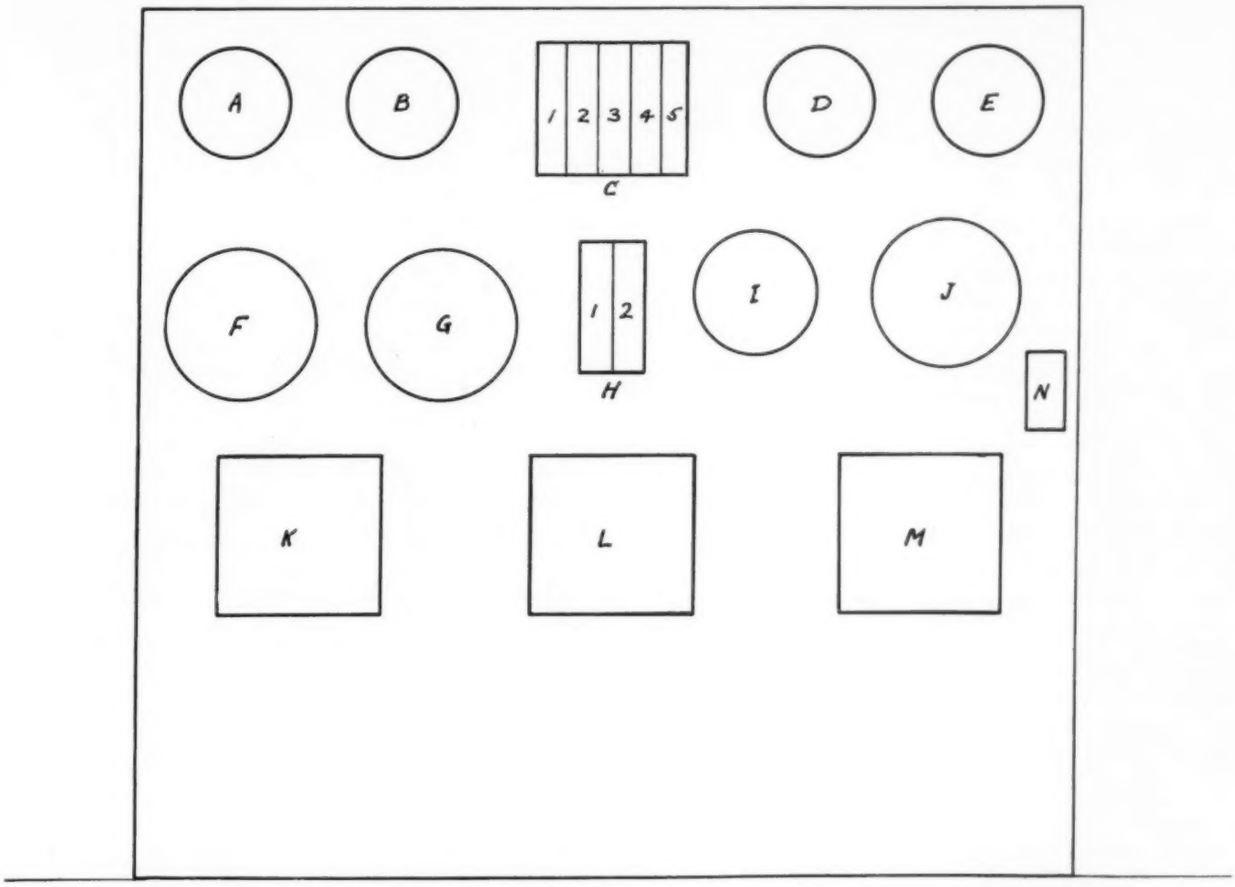


FIG. 4.



A-Oil Pressure
B-Steam Pressure
C1-Pressure in South Gas Regenerator
C2-Pressure in South Air Regenerator
C3-Draft at Entrance to Boiler.
C4-Pressure in North Air Regenerator
C5 Pressure in North Gas Regenerator
D Oil Temperature
E Steam Temperature
F-Oil Flow Meter-Recorder
G-Oil Flow Meter-Indicator
H1-Combustion Control-Blower Suction
H2-Combustion Control-Inlet Air Suction
I-Furnace Draft Recorder
J-CO_2 Recorder.
K-Temperatures of South Regenerators
L-Temperature of Gases Entering Boiler
M-Temperatures of North Regenerators
N-Push Button for Oil Control

FIG. 5.

a starting point, and, coupled with the diagram shown in Fig. I, would provide some interesting and helpful information which may at least surprise the engineering department of most concerns when comparing their own furnaces.

As previously stated it is comparatively easy to justify the use of any type of control equipment because of the consequent benefit to be derived from its use. The Lukens Steel Company had a slightly different problem than its colleagues in the industry in that more than 50 per cent of the oil used in the open hearth melting operations has a specific gravity of 1.06 while the remaining oil supply may vary in specific gravity to 0.972.

The simplest way of obtaining mechanical control is to apply the principle of flow measurement by balancing directly in one regulator, the drop in pressure across an orifice in the fuel oil line against the drop in pressure across an orifice in the air line. This type of regulator is installed in such a way that an increase in oil flow causes the increased drop in pressure to unbalance the regulator, thereby setting in action mechanism which changes the air flow to a point where the drop in pressure across the air orifice is again in equilibrium with the fuel oil drop.

Obviously we experienced difficulty in our attempts to meter this oil of varying gravity and met with like difficulties when attempting to control through an orifice. Consequently we decided to use a more positive method using the Paulsen Liquid Fuel Control. This liquid fuel system is based on the fact that a positive pressure pump connected in the fuel oil line to the furnace, with equal pressures at the inlet and outlet of the pump, will deliver liquid fuel in direct proportion to the speed of the pump. In other words, the pump is used as a meter. Then, by connecting a small fan or blower in line with the pump so that its speed is a multiple of the speed of the pump, the free delivery of air from the blower is a direct measure of the volume of liquid fuel delivered to the furnace. The inlet of this blower is equipped with a suction pipe having an orifice at the end, so that the drop in pressure across the orifice may be used as a measure of the flow in liquid fuel. This drop in pressure is then balanced in a regulator against the drop in pressure across the inlet orifice of the fan supplying air for combustion. Thereby, with correct orifice relationship established, the proper air for combustion of any flow of liquid fuel is secured. An illustration of this control is shown in Fig. 2 and explained in Fig. 3. The instrument board for this installation is shown on Fig. 4, and explained on Fig. 5.

Other writers on the subject of control have pointed out the difficulty of checking the control efficiency. To obtain gas analysis from the outgoing port of representative gases over a long period of time involves water cooled equipment of very special design on account of the fact that the sample tube must obtain its sample from several points in the gas stream simultaneously. So for purposes of checking as closely as possible the function of the control, we installed an air flow, oil flow recorder which, although subject to the usual application errors, shows conclusively that, once balanced, the control acts in accordance with the purpose of its design. A copy of an average recorder chart is shown in Fig. 6.

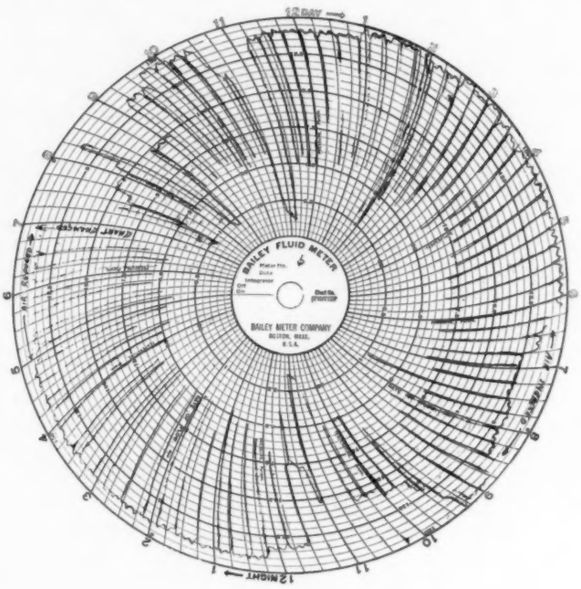


FIG. 6

The shop practice is an all cold metal charge and bottom poured practice, low carbon and special steels going to make up the bulk of the steel production.

From the data it will be noticed that the refractory saving is of equal importance and value to the fuel saving, this fact is confirmed in general practice as usually a controlled furnace will produce more heats per campaign than one which is not controlled. The use of control in protecting certain parts of the furnace has consequently brought out the weaknesses of design in other portions of the furnace, the most important being the roof especially where sloping backwalls are in use. This does not mean that our roof life is depreciating, but rather that it is not lasting in proportion to the other parts of the furnace, and there is little doubt that this can be overcome by the use of suspended construction and the use of open hearth furnace control will of necessity be followed by the more general use of suspended open hearth roofs.

Checker Temperature Control. At the present time we are reversing by hand using as a guide the readings from recording pyrometers which are of the duplex type, recording the temperatures in both the air and gas checkers, and as we have slide damper valves, we can readily adjust the flow of gases to balance up the individual chambers when they differ. Much can be said in favor of checker temperature control but in our case we have not yet completely worked out mechanism which we think would suit our purpose but we feel that we will ultimately adopt this additional refinement just as soon as we have worked out a simple mechanism that will suit our conditions and be dependable.

The savings accruing from the use of this control are as set out below. The figures are all based on gross tons of ingots, and included in the computation are all of the incidentals consequent to open hearth operation such as stock and bottom delays, minor mechanical and brickwork repairs, etc.

SAVINGS PER G. T. OF PRODUCTION AND RETURN ON INVESTMENT ACCOUNT INSTALLATION OF OPEN HEARTH FURNACE FUEL CONTROL

	#15 O. H. Furnace	#19 O. H. Furnace	#24 O. H. Furnace
Gallons Per G. T. before Installations	46.2	47.0	47.0
Gallons Per G. T. after Installations	38.8	40.5	42.4
Gallons Per G. T. Saving	7.4	6.5	4.6
Value of Gallon Per Tons	.234	.206	.146
Rebuilding Cost before Installation	.735	.739	.674
Rebuilding Cost after Installation	.535*	.539	.423
Rebuilding Cost Saving Per G. T.	.200	.200	.251
Total Saving Per G. T.	.434	.406	.397
Yearly Production	37,000	47,000	47,000
Value of Yearly Saving	16,058.00	19,082.00	18,659.00
Cost of Equipment	11,500.00**	13,500.00**	13,500.00**
Yearly Per cent of Return	140%	141%	138%

* Run not completed, cost estimated.

** Includes cost of installation, meters, recording instruments, etc.

Stack Draft Control. With proportionate supply of air to fuel established air infiltration must be prevented or at least be brought down to a minimum. This can be taken care of partially by machine regulation of the stack damper or induced draft fan. By keeping the center of the furnace as close to neutral as possible cold air infiltration on the incoming end will be prevented and peak flame temperature prevail. Air infiltration on the outgoing end will be minimized and the gases of combustion relieved of the ballast which they usually carry where furnace pressure control is not in use. The selection of the point from which this pressure is to be controlled is very important and in our early experiments we made connections in rear center of the roof, at two points in the back wall and at two points in the ports and downtakes. We eventually decided on the frontwall as close to the center as possible, and while this point has proven most successful, we are not ready to say that we have the correct location.

Very early in our experiments we found that pressure control of an open hearth furnace differed considerable from that of a boiler, and that the application of then available equipment was not entirely suitable.

The best system we have until the present found is the thermometric draft control. A system in which the motivating force on the regulator, or, the changes in furnace pressure, is multiplied many times, thereby making the control more sensitive to the slight changes in furnace pressure. Earlier in this paper I stated in effect, that any type of control was justified and I mean that literally; however, the steel plant engineer must look for the best in control equipment for the amount invested, and to say the least, very rapid strides have been made by manufacturers and operators alike in the design of this comparatively new application.

The equipment manufacturers as a body have responded readily to our every demand, but there are many phases of the control problem that we as Combustion Engineers must as a body concur on, before we can benefit to the full extent by the efforts of those who are trying to design equipment to suit our problems.

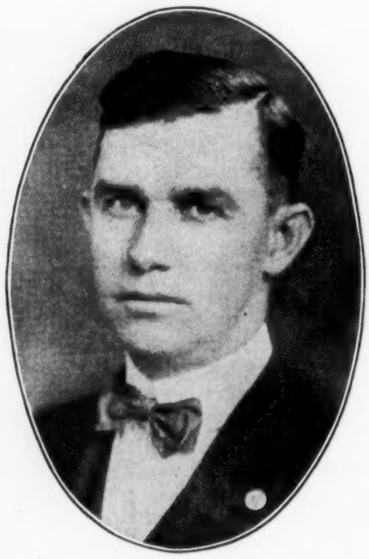
Furnace Control, entirely or in part, for the open hearth furnace is a problem of the application of well known principles of regulation to suit individual furnace requirements. It calls for the complete cooperation of furnace operators and intelligent research of the various departmental superintendents concerned for the successful application of the principles.

VISITING ENGINEERS are cordially invited to avail themselves of the facilities of the Cleveland Engineering Society. Club Rooms at Carnegie Hall, Eleventh Floor, 1220 Huron Road, open from 8:30 A. M. to 10:00 P. M. daily.

Preliminary Report of the Association of Iron and Steel Electrical Engineers Special Committee on Bearings†

By F. D. EGAN,* Chairman

The Special Committee on Bearings of the Association of Iron and Steel Electrical Engineers present herewith, their annual report for the year 1931 on investigation and tabulation of data and practices in the application of Anti-Friction Bearings to Mill Motors, General Purpose Motors, Electric Overhead Traveling Cranes and Mill Roll Necks. This report is supplementary to the data and information which has already been published by the Committee in the June, 1929, and June, 1930, issues of the Iron and Steel Engineer.



F. D. EGAN

It was pointed out in the last report by the Committee that data pertaining to anti-friction bearing application on Mill motors as published in Part I of the report included only data on roller bearing application on these motors inasmuch as the "Standards Committee of Association of Iron and Steel Electrical Engineers," had previously recommended the 300 series roller bearings for Mill Type Motors. In later activities of the Special Committee on Bearings, however, considerable discussion has developed relative to the application of double row ball bearings on Mill Type Motors. Both the Mill Type Motor Manufacturers and the Ball Bearing Manufacturers have brought out the fact that the double row ball bearing is interchangeable in mounting dimensions with most roller bearings and have in many cases, been applied on Mill Type Motors to satisfy the customer's specifications. The Committee is, therefore, justified in collecting and tabulating the data on the application of the double row ball bearing to the Mill Type Motor. This information is included in the tabulated data as follows: Table A-5, Double Row Ball Bearings for W. E. M. Co. MC Motors. Table A-6, Double Row Ball Bearings for G. E. Co. Mill Motors.

It has developed, since operating experience has become more general with the placing in operation of more anti-friction bearing equipped mill motors, that consideration must be given to several factors or operating conditions to insure success with the anti-friction bearing equipped motors. The Mill Motor Manufacturers are rating the compound and shunt wound motors for relatively high speeds and the tendency of machinery builders is for higher speed motors. This in turn, imposes relatively high peripheral speed on the raceways of the anti-friction bearings, particularly in the larger sizes.

The use of higher speed motors also exaggerates the problem of proper lubrication of anti-friction bearings and safe operating temperatures for these bearings. Very little reliable operating information is available on temperature rise and maximum temperatures for anti-friction bearings on Mill Motors. It was brought out by the Motor Manufacturers that in some cases, customers became concerned about safe operation of anti-friction bearing equipped motors due to heating in the bearings and the motor builders are not in position to advise what is maximum safe operating temperature for the bearings.

In one instance, a test was conducted on mill type motor equipped with #319 size roller bearings running light on test block at 1200 r.p.m. to measure on thermometer maximum bearing temperature attained and temperature rise above ambient. The peripheral speed of bearing was computed at 1570 F.P.M. with motor running at 1200 r.p.m. The bear-

* Electrical Superintendent, Bethlehem Steel Company, Lackawanna, N. Y.

† Final report will appear in an early issue of Iron & Steel Engineer.

ing temperature was measured with mercury type thermometers inserted in the bearing cartridge through hole for grease fitting. The test was conducted under two different conditions of lubrication. In the first case, the bearings were run and temperature measured for lubrication as issued in bearings from Motor Factory. A maximum temperature rise of 120 degrees above ambient was obtained under these conditions. In the second case, the original lubricant was washed out of bearings and it was relubricated with another grade of grease. In this case, the maximum bearing temperature obtained after operating motor at 1200 r.p.m. for three hours was 148 degrees Fahrenheit, or 76 degrees rise above ambient temperature, a difference of 44 degrees Fahrenheit in the temperature rise for the two grades of lubricant.

It has been suggested that oil is more satisfactory lubricant for anti-friction bearings operating at relatively high speeds and temperatures. The argument put forth in favor of this idea is the fact that grease lubrication under conditions of high speed and temperatures disintegrates, thereby losing its effectiveness as a lubricant causing additional heating and tending toward early failure of the bearing.

From an operation standpoint, the introduction of oil lubrication in these bearings defeats one of the prime reasons for acceptance of anti-friction bearings on electric motors by the operating men. At high speeds, the oil tends to vaporize and leak out of the bearings saturating the commutators and windings of the motors and tending toward early failure of the motors. For this reason, it was felt that anti-friction bearings which could be satisfactorily lubricated with grease would insure longer motor life in operation.

The problem of lubrication, maximum speed determination, and heating for anti-friction bearings on Mill Motors is further complicated by conditions surrounding the drive. In many instances, considerable thrust is imposed axially on the armature shaft from helical gearing, inclination of motor base or some other condition of the drive. The thrust condition develops additional heating in the motor bearings unless a special thrust bearing is provided to handle the thrust.

The Special Committee on Bearings are endeavoring to obtain a composite opinion of the Operating Men, Motor Manufacturers and Bearing Manufacturers, relative to heating, thrust, and lubrication of anti-friction bearings when operating at relatively high speeds, through circulation of a questionnaire by the Association of Iron and Steel Electrical Engineers. It is expected that this information will be developed and in shape for publication at some future date.

Part II of the Committee's report in 1930 on, "Application of Anti-Friction Bearings to General Purpose Motors" was quite thoroughly covered as evidenced by the number of tabulated data sheets on these motor frames. No more data has been developed and the Committee has nothing further to report under this caption at this time.

Part III, Application of Anti-Friction Bearings to Electric Overhead Traveling Cranes. Supplementing data published in the 1930 report, the Special Committee on Bearings has compiled and tabulated the following data for application of anti-friction bearings to Crane Bridge Lineshafts:

Tables D-6 and D-6-A, Morgan Engineering Co.

Tables D-7, D-7-A and D-7-B, Alliance Machine Company.

Table D-8, Cleveland Crane & Engineering Co.

Table D-9, Harnischfeger Corp.

Table D-10, Shepard-Niles Crane & Hoist Corp.

The tabulation includes bearing data for bridge lineshafts ranging in size from 3⅜" to 5½" in diameter which was considered typical sizes for mill type cranes in steel mill service. It is expected that future activities of the Committee will include the development and tabulation of anti-friction bearing application to hoist and cross travel shafting as well as rope sheaves to complete data on anti-friction bearing equipped Electric Overhead Traveling Cranes.

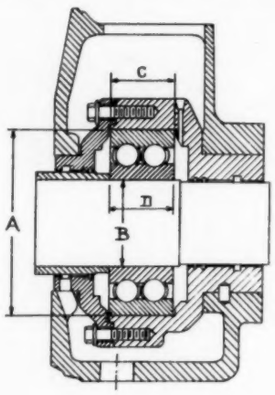
Part IV, Application of Anti-Friction Bearings to Mill Roll Necks.

This phase of the Committee's investigations has been approached from the practical angle of collecting and tabulating data on what has been accomplished in the field of application of Anti-Friction Bearings to Mill Roll Necks. Considerable theoretical and technical information has been developed by eminent engineers both in this country and abroad, on the subject of rolling pressures and methods of calculating their values, as a determining factor in the application of anti-friction bearings on Roll Necks. The anti-friction bearing manufacturers have spent considerable time and effort in research work to devise methods and develop practical apparatus for the accurate measurement by test, of forces and pressures exerted on roll necks as a means of determining proper bearing application in rolling mill service.

The Special Committee on Bearings considers that the responsibility for the correct solution of the problem of accurately determining rolling pressures, whether by theoretical calculation or actual physical measurement, rests largely with the Bearing Manufacturers assisted by Operating Engineers. In this light, it is felt that the Committee can now serve the cause to best advantage by collecting and tabulating data on existing applications which will serve as a pattern or guide for future applications.

To this end, the Committee has collected the Anti-Friction Bearing Manufacturer's data on a number of existing applications of their bearings to Mill Roll Necks and the information is presented in this report on tabulated sheets, E-1, E-2, and E-3.

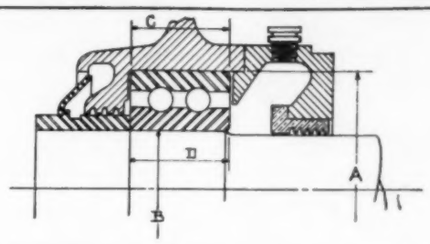
It is to be expected that information on the subject in this report will be supplemented and expanded in future investigations of the Committee to include new applications and that the co-operation effected thereby will enable the research engineers assisted by operating engineers to find a satisfactory solution to the accurate determination of rolling pressures.



WESTINGHOUSE MILL MOTORS

MOTOR DATA			DOUBLE ROW BALL BEARING DATA										
FRAME	HP	RPM	MFG.	SERIES	A	B	C	D	BALL Nº	BALL DIA.	SHAFT FIT	CART'G O.D.	FRAME BORE
20 MC	6	700	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5310	4.3307	1.9685	1.7500	1.7500	24	.6875	1.9690 1.9685	4.0020 4.0000	4.0030 4.0000
			FAFNIR	5310	4.3307	1.9685	1.7500	1.7500	24	.750	1.9690 1.9685	4.0020 4.0000	4.0030 4.0000
			GURNEY										
			N.DEPARTURE	5310	4.3307	1.9685	1.7500	1.7500	24	.6875	1.9690 1.9685	4.0020 4.0000	4.0030 4.0000
30 MC	12	700	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5313	5.5118	2.5591	2.3125	2.3125	24	.9375	2.5597 2.5592	4.6270 4.6250	4.6280 4.6250
			FAFNIR	5313	5.5118	2.5591	2.3125	2.3125	26	.9375	2.5597 2.5592	4.6270 4.6250	4.6280 4.6250
			GURNEY										
			N.DEPARTURE	5313	5.5118	2.5591	2.3125	2.3125			2.5597 2.5592	4.6270 4.6250	4.6280 4.6250
40 MC	20	600	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5315	6.2992	2.9528	2.6875	2.6875	26	1.00	2.9535 2.9530	5.2520 5.2500	5.2530 5.2500
			FAFNIR	5315	6.2992	2.9528	2.6875	2.6875	24	1.125	2.9535 2.9530	5.2520 5.2500	5.2530 5.2500
			GURNEY										
			N.DEPARTURE	5315	6.2992	2.9528	2.6875	2.6875			2.9535 2.9530	5.2520 5.2500	5.2530 5.2500
50 MC	30	525	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5315	6.2992	2.9528	2.6875	2.6875	26	1.00	2.9535 2.9530	5.2520 5.2500	5.2530 5.2500
			FAFNIR	5315	6.2992	2.9528	2.6875	2.6875	24	1.125	2.9535 2.9530	5.2520 5.2500	5.2530 5.2500
			GURNEY										
			N.DEPARTURE	5315	6.2992	2.9528	2.6875	2.6875			2.9535 2.9530	5.2520 5.2500	5.2530 5.2500
60 MC	50	525	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5319	7.8740	3.7402	3.0625	3.0625	26	1.250	3.7410 3.7405	6.2520 6.2500	6.2530 6.2500
			FAFNIR	5319	7.8740	3.7402	3.0625	3.0625	24	1.375	3.7410 3.7405	6.2520 6.2500	6.2530 6.2500
			GURNEY										
			N.DEPARTURE										
70 MC	70	475	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5319	7.8740	3.7402	3.0625	3.0625	26	1.250	3.7410 3.7405	6.2520 6.2500	6.2530 6.2500
			FAFNIR	5319	7.8740	3.7402	3.0625	3.0625	24	1.375	3.7410 3.7405	6.2520 6.2500	6.2530 6.2500
			GURNEY										
			N.DEPARTURE										
80 MC	85	480	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5322	9.4488	4.3307	3.6250	3.6250	26	1.500	4.3315 4.3310	7.0020 7.0000	7.0030 7.0000
			FAFNIR	5322	9.4488	4.3307	3.6250	3.6250	24	1.625	4.3315 4.3310	7.0020 7.0000	7.0030 7.0000
			GURNEY										
			N.DEPARTURE										
90 MC	100	500	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.	5324	10.2362	4.7244	4.1250	4.1250			4.7255 4.7250	7.3770 7.3750	7.3780 7.3750
			FAFNIR	5324	10.2362	4.7244	4.1250	4.1250	24	1.750	4.7255 4.7250	7.3770 7.3750	7.3780 7.3750
			GURNEY										
			N.DEPARTURE										
100 MC	150	370	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.										
			FAFNIR	5326 SPEC. BORE	11.0236	5.2362	4.3750	4.3750	24	1.875	5.2370 5.2365	8.2520 8.2500	8.2530 8.2500
			GURNEY										
			N.DEPARTURE										
103 MC	180	475	S.K.F.	RECOMMEND 52300 SERIES ROLLER BEARINGS									
			S.R.B.										
			FAFNIR	5326 SPEC. BORE	11.0236	5.2362	4.3750	4.3750	24	1.875	5.2370 5.2365	8.2520 8.2500	8.2530 8.2500
			GURNEY										
			N.DEPARTURE										

Table - A5

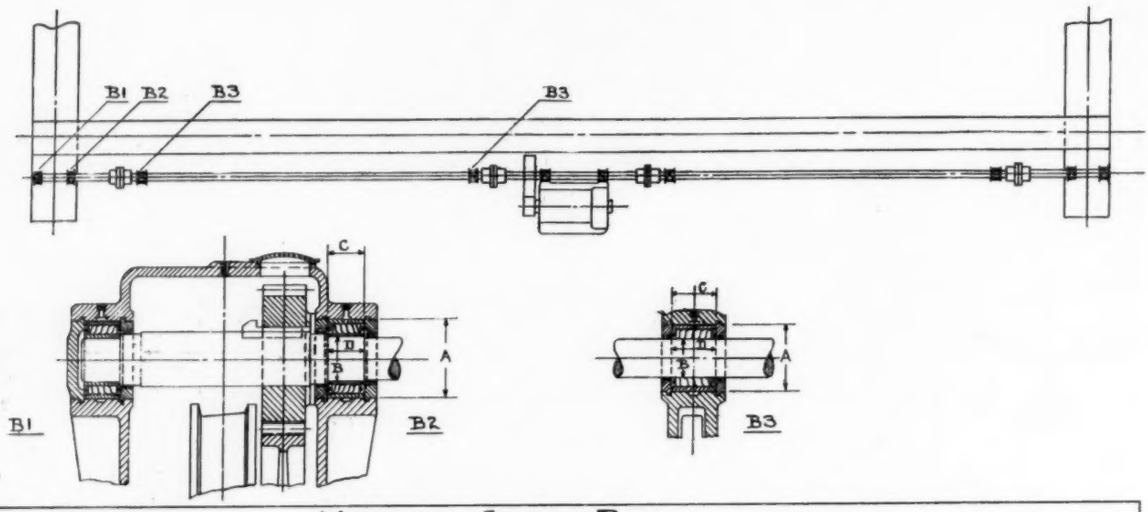


GENERAL ELECTRIC MILL MOTORS

MOTOR DATA			DOUBLE ROW BALL BEARING DATA										
FRAME	HP	RPM	M'F'G.	SERIES	A	B	C	D	BALL Nº	BALL DIA.	SHAFT FIT	CART'G O.D.	FRAME BORE
MD402	5	900	S.K.F.	5309	3.9370 3.9362	1.7717 1.7712	1.5625	1.5625	16	.625	1.7726 1.7721		3.9378 3.9373
			S.R.B.	5309	3.9370 3.9362	1.7717 1.7712	1.5625 1.5575	1.5625 1.5575	24	.625	1.7726 1.7721		3.9378 3.9373
			FAFNIR	5309	3.9370 3.9362	1.7717 1.7712	1.5625 1.5575	1.5625 1.5575	24	.6875	1.7726 1.7721		3.9378 3.9373
			GURNEY	5309R	3.9370 3.9362	1.7717 1.7712	1.5625 1.5575	1.5625 1.5575	24	.625	1.7726 1.7721		3.9378 3.9373
			N.DEPARTURE	5309	3.9370 3.9362	1.7717 1.7712	1.5625	1.5625	26	.5937	1.7726 1.7721		3.9378 3.9373
MD403	7½	800	S.K.F.	5311	4.7244 4.7236	2.1654 2.1648	1.9375	1.9375	16	.750	2.1665 2.1660		4.7253 4.7248
			S.R.B.	5311	4.7244 4.7236	2.1654 2.1648	1.9375 1.9325	1.9375 1.9325	22	.8125	2.1665 2.1660		4.7253 4.7248
			FAFNIR	5311	4.7244 4.7236	2.1654 2.1648	1.9375 1.9325	1.9375 1.9325	24	.8125	2.1665 2.1660		4.7253 4.7248
			GURNEY	5311R	4.7244 4.7236	2.1654 2.1648	1.9375 1.9325	1.9375 1.9325	24	.750	2.1665 2.1660		4.7253 4.7248
			N.DEPARTURE	5311	4.7244 4.7236	2.1654 2.1648	1.9375	1.9375	24	.750	2.1665 2.1660		4.7253 4.7248
MD404	10	725	S.K.F.	5311	4.7244 4.7236	2.1654 2.1648	1.9375	1.9375	16	.750	2.1665 2.1660		4.7253 4.7248
			S.R.B.	5311	4.7244 4.7236	2.1654 2.1648	1.9375 1.9325	1.9375 1.9325	22	.8125	2.1665 2.1660		4.7253 4.7248
			FAFNIR	5311	4.7244 4.7236	2.1654 2.1648	1.9375 1.9325	1.9375 1.9325	24	.8125	2.1665 2.1660		4.7253 4.7248
			GURNEY	5311R	4.7244 4.7236	2.1654 2.1648	1.9375 1.9325	1.9375 1.9325	24	.750	2.1665 2.1660		4.7253 4.7248
			N.DEPARTURE	5311	4.7244 4.7236	2.1654 2.1648	1.9375	1.9375	24	.750	2.1665 2.1660		4.7253 4.7248
MD406	15	650	S.K.F.	5313	5.5118 5.5108	2.5591 2.5585	2.3125	2.3125	16	.875	2.5605 2.5598		5.5128 5.5123
			S.R.B.	5313	5.5118 5.5108	2.5591 2.5585	2.3125 2.3075	2.3125 2.3075	24	.9375	2.5605 2.5598		5.5128 5.5123
			FAFNIR	5313	5.5118 5.5108	2.5591 2.5585	2.3125 2.3075	2.3125 2.3075	26	.9375	2.5605 2.5598		5.5128 5.5123
			GURNEY	5313R	5.5118 5.5108	2.5591 2.5585	2.3125 2.3075	2.3125 2.3075	28	.875	2.5605 2.5598		5.5128 5.5123
			N.DEPARTURE	5313	5.5118 5.5108	2.5591 2.5585	2.3125	2.3125	24	.9062	2.5605 2.5598		5.5128 5.5123
MD407			S.K.F.	5314	5.9055 5.9045	2.7559 2.7553	2.5000	2.5000	16	.9375	2.7565 2.7560		5.9068 5.9063
			S.R.B.	5314	5.9055 5.9043	2.7559 2.7553	2.5000 2.4950	2.5000 2.4950	24	1.000	2.7565 2.7560		5.9068 5.9063
			FAFNIR	5314	5.9055 5.9043	2.7559 2.7553	2.5000 2.4950	2.5000 2.4950	26	1.000	2.7565 2.7560		5.9068 5.9063
			GURNEY	5314R	5.9055 5.9043	2.7559 2.7553	2.5000 2.4950	2.5000 2.4950	28	.9375	2.7565 2.7560		5.9068 5.9063
			N.DEPARTURE	5314	5.9055 5.9045	2.7559 2.7553	2.5000	2.5000	24	.9687	2.7565 2.7560		5.9068 5.9063
MD408	25	575	S.K.F.	5316	6.6935 6.6915	3.1496 3.1490	2.6875	2.6875	16	1.0625	3.1507 3.1502		6.6939 6.6934
			S.R.B.	5316	6.6935 6.6917	3.1496 3.1490	2.6875 2.6825	2.6875 2.6825	26	1.0625	3.1507 3.1502		6.6939 6.6934
			FAFNIR	5316	6.6935 6.6917	3.1496 3.1490	2.6875 2.6825	2.6875 2.6825	24	1.1875	3.1507 3.1502		6.6939 6.6934
			GURNEY	5316R	6.6935 6.6917	3.1496 3.1490	2.6875 2.6825	2.6875 2.6825	28	1.0625	3.1507 3.1502		6.6939 6.6934
			N.DEPARTURE	5316	6.6935 6.6917	3.1496 3.1490	2.6875	2.6875	24	1.0625	3.1507 3.1502		6.6939 6.6934
MD410	35	525	S.K.F.	5317	7.0866 7.0856	3.3465 3.3457	2.8750	2.8750	16	1.125	3.3475 3.3470		7.0877 7.0872
			S.R.B.	5317	7.0866 7.0854	3.3465 3.3458	2.8750 2.8700	2.8750 2.8700	26	1.1875	3.3475 3.3470		7.0877 7.0872
			FAFNIR	5317	7.0866 7.0854	3.3465 3.3458	2.8750 2.8700	2.8750 2.8700	24	1.250	3.3475 3.3470		7.0877 7.0872
			GURNEY	5317R	7.0866 7.0854	3.3465 3.3458	2.8750 2.8700	2.8750 2.8700	28	1.125	3.3475 3.3470		7.0877 7.0872
			N.DEPARTURE	5317	7.0866 7.0856	3.3465 3.3457	2.8750	2.8750	24	1.125	3.3475 3.3470		7.0877 7.0872
MD412	50	500	S.K.F.	5319	7.8740 7.8728	3.7402 3.7394	3.0625	3.0625	16	1.250	3.7415 3.7410		7.8750 7.8745
			S.R.B.	5319	7.8740 7.8728	3.7402 3.7395	3.0625 3.0575	3.0625 3.0575	26	1.250	3.7415 3.7410		7.8750 7.8745
			FAFNIR	5319 *							3.7415 3.7410		7.8750 7.8745
			GURNEY	5319R	7.8740 7.8728	3.7402 3.7395	3.0625 3.0575	3.0625 3.0575	28	1.250	3.7415 3.7410		7.8750 7.8745
			N.DEPARTURE	5319 *							3.7415 3.7410		7.8750 7.8745
MD414	75	475	S.K.F.	5322	9.4488 9.4476	4.3307 4.3299	3.6250	3.6250	16	1.500	4.3320 4.3315		9.4502 9.4492
			S.R.B.	5322	9.4488 9.4476	4.3307 4.3300	3.6250 3.6200	3.6250 3.6200	26	1.500	4.3320 4.3315		9.4502 9.4492
			FAFNIR	5322 *							4.3320 4.3315		9.4502 9.4492
			GURNEY	5322R	9.4488 9.4476	4.3307 4.3300	3.6250 3.6200	3.6250 3.6200	28	1.500	4.3320 4.3315		9.4502 9.4492
			N.DEPARTURE	5322 *							4.3320 4.3315		9.4502 9.4492
MD416	100	460	S.K.F.	5324 *							4.7260 4.7255		10.2376 10.2366
			S.R.B.								4.7260 4.7255		10.2376 10.2366
			FAFNIR								4.7260 4.7255		10.2376 10.2366
			GURNEY								4.7260 4.7255		10.2376 10.2366
			N.DEPARTURE								4.7260 4.7255		10.2376 10.2366
MD418	150	450	S.K.F.	5326 *							5.1192 5.1187		11.0256 11.0236
			S.R.B.								5.1192 5.1187		11.0256 11.0236
			FAFNIR								5.1192 5.1187		11.0256 11.0236
			GURNEY								5.1192 5.1187		11.0256 11.0236
			N.DEPARTURE								5.1192 5.1187		11.0256 11.0236
MD420	275	375	S.K.F.								5.9072 5.9067		10.6314 10.6304
			S.R.B.								5.9072 5.9067		10.6314 10.6304
			FAFNIR								5.9072 5.9067		10.6314 10.6304
			GURNEY								5.9072 5.9067		10.6314 10.6304
			N.DEPARTURE								5.9072 5.9067		10.6314 10.6304

* NOT LISTED

TABLE-A6



MORGAN CRANE DATA

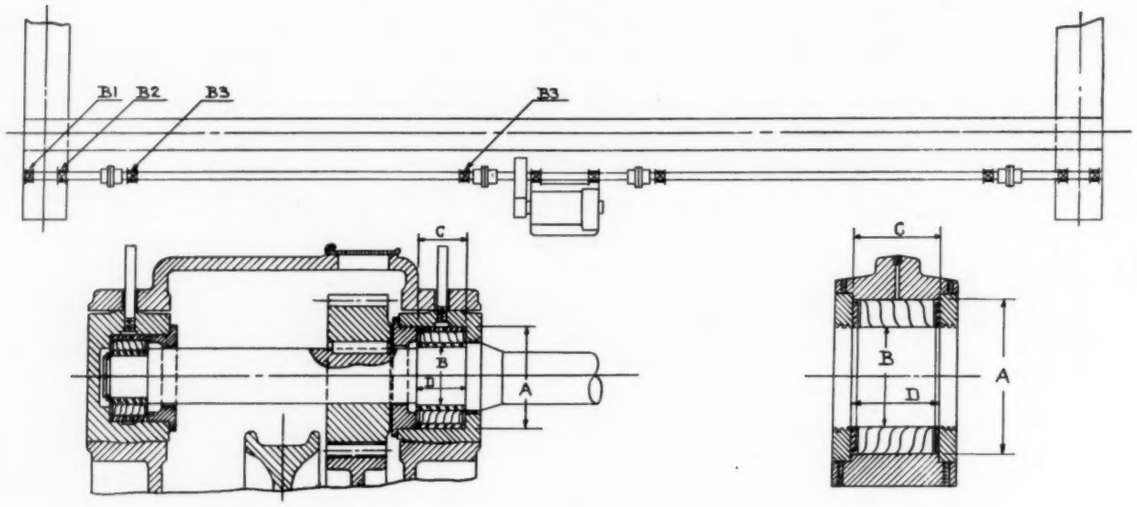
NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT
3 3/8"	B1	HYATT	W-216		3.1513 3.1506				5.5135 5.5116	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN								
	B2	HYATT	W-216		3.1513 3.1506				5.5135 5.5116	
		TIMKEN								
		ROLLWAY								
		N. HOFFMANN								
	B3	HYATT	40010		3.5000 3.4960				6.1250 6.1250	
		TIMKEN								
		ROLLWAY								
		N. HOFFMANN								
3 1/2"	B1	HYATT	W-217		3.3482 3.3475	2.7500			5.9073 5.9053	
		TIMKEN								
		ROLLWAY								
		N. HOFFMANN	RLS-20		3.5000	1.1250		+.0002 +.0007	6.5000	-.0008 -.0013
	B2	HYATT	W-217		3.3482 3.3475	2.7500			5.9073 5.9053	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-20		3.5000	1.1250		+.0002 +.0007	6.5000	-.0008 -.0013
	B3	HYATT	40010		3.5000 3.4960	4.0000			6.1250 6.1250	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLTN-21		3.5000	1.3125			7.7500	-.0003 -.0008
3 3/4"	B1	HYATT	W-219		3.7421 3.7413				6.6548 6.6926	
		TIMKEN								
		ROLLWAY								
		N.HOFFMAN	RLS-20½		3.7500	1.1250		+.0002 +.0007	6.7500	-.0008 -.0013
	B2	HYATT	W-219		3.7421 3.7413				6.6548 6.6926	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-20½		3.7500	1.1250		+.0002 +.0007	8.0000	
	B3	HYATT	40061		4.0000 3.9960				6.6250 6.6250	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLTN-21½		3.7500	1.3125			8.0000	-.0003 -.0008
4"	B1	HYATT	W-220		3.9350 3.9382	3.2500			7.0886 7.0863	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-21		4.0000	1.2500		+.0002 +.0007	7.2500	-.0008 -.0013
	B2	HYATT	W-220		3.9350 3.9382	3.2500			7.0886 7.0863	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-21		4.0000	1.2500		+.0002 +.0007	7.2500	

TABLE-D6

MORGAN CRANE DATA

NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT
4"	B3	HYATT	40061		4.0000 3.9960	4.0000			6.6250 6.6250	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLTN-22		4.0000	1.3750			8.5000	+.0003 -.0008
4¼"	B1	HYATT	W-222		4.3328 4.3320				7.8762 7.8737	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-21½		4.2500	1.2500		+.0005 +.0010	7.5000	+.0008 -.0013
	B2	HYATT	W-222		4.3328 4.3320				7.8762 7.8737	
		TIMKEN								
		ROLLWAY								
		N. HOFFMANN	RLS-21½		4.2500	1.2500		+.0005 +.0010	7.5000	
	B3	HYATT	40360		4.5000 4.4960				7.3800 7.3750	
		TIMKEN								
		ROLLWAY								
		N. HOFFMANN	RLTN-22½		4.2500	1.3750			8.7500	+.0003 -.0008
4½"	B1	HYATT	W-222		4.3328 4.3320	3.5000			7.8762 7.8737	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-22		4.5000	1.3125			8.0000	+.0008 -.0013
	B2	HYATT	W-222		4.3328 4.3320	3.5000			7.8762 7.8737	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-22		4.5000	1.3125			8.0000	
	B3	HYATT	40360		4.5000 4.4960	4.0000			7.3800 7.3750	
		TIMKEN								
		ROLLWAY								
		N. HOFFMANN	RLTN-23		4.5000	1.4375			9.6250	+.0003 -.0008
4¾"	B1	HYATT	W-224		4.7267 4.7258				8.4669 8.4643	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-22½		4.7500	1.3125			8.2500	+.0008 -.0013
	B2	HYATT	W-224		4.7267 4.7258				8.4669 8.4643	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-22½		4.7500	1.3125			8.2500	
	B3	HYATT	40410		5.0000 4.9950				7.8800 7.8750	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLTN-23½		4.7500	1.4375			10.1250	+.0003 -.0008
5"	B1	HYATT	W-224		4.7267 4.7258	3.8750			8.4669 8.4643	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN								
	B2	HYATT	W-224		4.7267 4.7258	3.8750			8.4669 8.4643	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN								
	B3	HYATT	40410		5.0000 4.9950	4.0000			7.8800 7.8750	
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN								
5½"	B1	HYATT								
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-23½		5.5000	1.3750			9.5000	+.0008 -.0013
	B2	HYATT								
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLS-23½		5.5000	1.3750			9.5000	
	B3	HYATT								
		TIMKEN								
		ROLLWAY								
		N.HOFFMANN	RLTN-24		5.5000	1.6250			11.1250	+.0003 -.0008

Table - D6a



ALLIANCE CRANE DATA

NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT	
3 3/8"	B1	HYATT	W-215					2.3544 2.3537	5.1157 5.1179		
		TIMKEN	759-752	6.3760 6.3750	3.5010 3.5000	1.8750			6.3770 6.3750		
		ROLLWAY	MF-5218					3.5443 3.5435	6.3012 6.2992		
		N.HOFFMANN	R-190					3.5440 3.5435	6.2990 6.2985		
		S.K.F.	22218					3.5445 3.5436	6.3006 6.2992		
	B2	HYATT	W-219					3.7421 3.7413	6.6948 6.6926		
		TIMKEN	759-752	6.3760 6.3750	3.5010 3.5000	1.8750			6.3770 6.3750		
		ROLLWAY	MF-5218					3.5443 3.5435	6.3012 6.2992		
		N.HOFFMANN	R-190					3.5440 3.5435	6.2990 6.2985		
		S.K.F.	22218					3.5445 3.5436	6.3006 6.2992		
	B3	R.B.OF A.			3.3750	2.5000					
		DODGE TIMKEN	PILLOW BLOCK								
		ROLLWAY									
		N.HOFFMANN									
		S.K.F.	PILLOW BLOCK								
3½"	B1	HYATT	W-215					2.3544 2.3537	5.1157 5.1179		
		TIMKEN	759-752	6.3760 6.3750	3.5010 3.5000	1.8750			6.3770 6.3750		
		ROLLWAY	MF-5218					3.5443 3.5435	6.3012 6.2992		
		N.HOFFMANN	R-190					3.5440 3.5435	6.2990 6.2985		
		S.K.F.	22218					3.5445 3.5436	6.3006 6.2992		
	B2	HYATT	W-219					3.7421 3.7413	6.6948 6.6926		
		TIMKEN	759-752	6.3760 6.3750	3.5010 3.5000	1.8750			6.3770 6.3750		
		ROLLWAY	MF-5218					3.5443 3.5435	6.3012 6.2992		
		N.HOFFMANN	R-190					3.5440 3.5435	6.2990 6.2985		
		S.K.F.	22218					3.5445 3.5436	6.3018 6.2992		
	B3	R.B.OF A.									
		DODGE TIMKEN	PILLOW BLOCK								
		ROLLWAY	WS								
		N.HOFFMANN	RLT-21					3.5007 3.5002	7.2485 7.2480		
		S.K.F.	PILLOW BLOCK								

Table - D7

ALLIANCE CRANE DATA

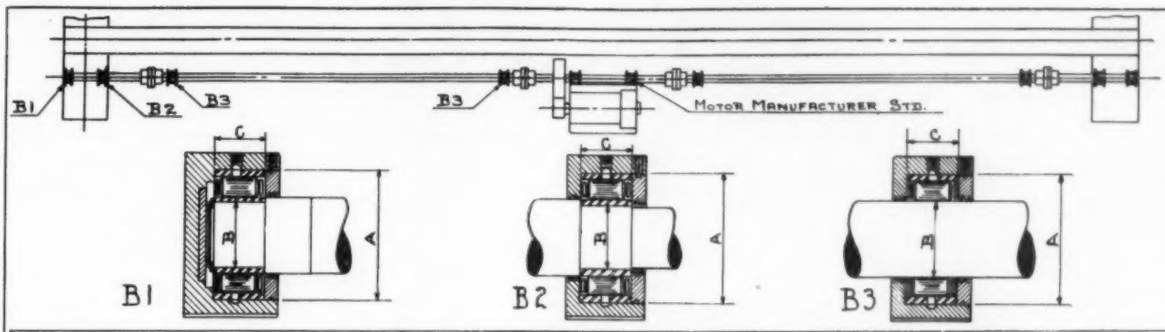
NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT
3¾"	B1	HYATT	W-215					3.9544 3.9537	5.1187 5.1179	
		TIMKEN	779-772						7.1270 7.1250	
		ROLLWAY	MF-5218					3.5443 3.5435	6.3012 6.2992	
		N.HOFFMANN	R-190					3.5440 3.5435	6.2990 6.2985	
		S.K.F.	22218					3.5445 3.5436	6.3018 6.2992	
	B2	HYATT	W-219					3.7421 3.7413	6.6948 6.6926	
		TIMKEN	779-772						7.1270 7.1250	
		ROLLWAY	MF-5218					3.5443 3.5435	6.3012 6.2992	
		N.HOFFMANN	R-190					3.5440 3.5435	6.2990 6.2985	
		S.K.F.	22218					3.5445 3.5436	6.3018 6.2992	
	B3	R.B. OF A								
		DODGE TIMKEN	PILLOW BLOCK							
		ROLLWAY								
		N.HOFFMANN	RLT-21½					3.7507 3.7502	7.4985 7.4980	
		S.K.F.	PILLOW BLOCK							
4"	B1	HYATT	W-216					3.1513 3.1506	5.5135 5.5116	
		TIMKEN	780-772	7.1260 7.1250	4.0000 4.0010	1.8750			7.1270 7.1250	
		ROLLWAY	MF-5220					3.9380 3.9372	7.0906 7.0886	
		N.HOFFMANN	R-200					3.9377 3.9372	7.0864 7.0859	
		S.K.F.	22220					3.9382 3.9373	7.0892 7.0866	
	B2	HYATT	W-220					3.9390 3.9382	7.0886 7.0863	
		TIMKEN	780-772	7.1260 7.1250	4.0010 4.0000	1.8750			7.1270 7.1250	
		ROLLWAY	MF-5220					3.9380 3.9372	7.0906 7.0886	
		N.HOFFMANN	R-200					3.9377 3.9372	7.0864 7.0859	
		S.K.F.	22220					3.9382 3.9373	7.0892 7.0866	
	B3	HYATT	WRA-217							
		DODGE TIMKEN	PILLOW BLOCK							
		ROLLWAY	WS							
		N.HOFFMANN	RLT-22					4.0007 4.0002	7.9985 7.9980	
		S.K.F.	PILLOW BLOCK							
4¼"	B1	HYATT	W-216					3.1513 3.1506	5.5135 5.5116	
		TIMKEN	71425-71750	7.5010 7.5000	4.2510 4.2500	1.8750			7.5020 7.5000	
		ROLLWAY	MF-5220					3.9380 3.9372	7.0906 7.0886	
		N.HOFFMANN	R-200					3.9377 3.9372	7.0864 7.0859	
		S.K.F.	22220					3.9382 3.9373	7.0892 7.0866	
	B2	HYATT	W-220					3.9390 3.9382	7.0886 7.0863	
		TIMKEN	71425-71750	7.5010 7.5000	4.2510 4.2500	1.8750			7.5020 7.5000	
		ROLLWAY	MF-5220					3.9380 3.9372	7.0906 7.0886	
		N.HOFFMANN	R-200					3.9377 3.9372	7.0864 7.0859	
		S.K.F.	22220					3.9382 3.9373	7.0892 7.0866	
	B3	HYATT	WRA-218							
		DODGE TIMKEN	PILLOW BLOCK							
		ROLLWAY								
		N.HOFFMANN	RLT-22½					4.2510 4.2505	8.2485 8.2480	
		S.K.F.								
4½"	B1	HYATT	W-217					3.3482 3.3475	5.9073 5.9053	
		TIMKEN	71450-71750	7.5010 7.5000	4.2510 4.2500	1.8750			7.5020 7.5000	
		ROLLWAY	MF-5222					4.3317 4.3309	7.8760 7.8740	
		N.HOFFMANN	R-210					4.3317 4.3312	7.8738 7.8733	
		S.K.F.	22222					4.3315 4.3310	7.8748 7.8740	
	B2	HYATT	W-222					4.3328 4.3320	7.8762 7.8737	
		TIMKEN	71450-71750	7.5010 7.5000	4.2510 4.2500	1.8750			7.5020 7.5000	
		ROLLWAY	MF-5222					4.3317 4.3309	7.8760 7.8740	
		N.HOFFMANN	R-210					4.3317 4.3312	7.8738 7.8733	
		S.K.F.	22222					4.3315 4.3310	7.8748 7.8740	
	B3	HYATT	WRA-219							
		DODGE TIMKEN	PILLOW BLOCK							
		ROLLWAY	WS							
		N.HOFFMANN	RLT-23					4.5010 4.5005	8.9985 8.9980	
		S.K.F.	PILLOW BLOCK							

Table - D7a

ALLIANCE CRANE DATA

NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT	
4¾"	B1	HYATT	W-217					3.5482 3.3475	5.5073 5.5053		
		TIMKEN	71450-71750	7.5010 7.5000	4.5010 4.5000	1.8750			7.5020 7.5000		
		ROLLWAY	MF-5222					4.3317 4.3309	7.8760 7.8740		
		N.HOFFMANN	R-210					4.3317 4.3312	7.8738 7.8733		
		S.K.F.	22222					4.3315 4.3310	7.8768 7.8740		
	B2	HYATT	W-222					4.3328 4.3320	7.8762 7.8737		
		TIMKEN	71450-71750	7.5010 7.5000	4.5010 4.5000	1.8750			7.5020 7.5000		
		ROLLWAY	MF-5222					4.3317 4.3309	7.8760 7.8740		
		N.HOFFMANN	R-210					4.3317 4.3312	7.8738 7.8733		
		S.K.F.	22222					4.3315 4.3310	7.8768 7.8740		
	B3	HYATT	WRA-219								
		DODGE TIMKEN	PILLOW BLOCK								
		ROLLWAY									
		N.HOFFMANN	RLT-23					4.5010 4.5005	8.9985 8.9980		
		S.K.F.	PILLOW BLOCK								
5"	B1	HYATT	W-218					3.5451 3.5444	6.3011 6.2990		
		TIMKEN	74500-74850	8.5010 8.5000	4.5000 4.5000	1.8750			8.5020 8.5000		
		ROLLWAY	MF-5224					4.7254 4.7246	8.4694 8.4670		
		N.HOFFMANN	RLS-23-RR					5.0010 5.0005	8.9985 8.9980		
		S.K.F.	22224					4.7256 4.7247	8.4674 8.4646		
	B2	HYATT	W-224					4.7267 4.7258	8.4663 8.4643		
		TIMKEN	74500-74850	8.5010 8.5000	4.5000 4.5000	1.8750			8.5020 8.5000		
		ROLLWAY	MF-5224					4.7254 4.7246	8.4694 8.4670		
		N.HOFFMANN	RLS-23-RR					5.0010 5.0005	8.9985 8.9980		
		S.K.F.	22224					4.7256 4.7247	8.4674 8.4646		
	B3	HYATT	WRA-320								
		DODGE TIMKEN	PILLOW BLOCK								
		ROLLWAY	WS								
		N.HOFFMANN	RLT-23½					5.0010 5.0005	8.9985 8.9980		
		S.K.F.	PILLOW BLOCK								
5¼"	B1	HYATT	W-220					3.5350 3.9382	7.0886 7.0863		
		TIMKEN	74525-74850	8.5010 8.5000	4.5000 4.5000	1.8750			8.5020 8.5000		
		ROLLWAY	MF-5226					5.1153 5.1183	9.0600 9.0576		
		N.HOFFMANN	RLS-23-RR					5.0010 5.0005	8.9985 8.9980		
		S.K.F.	22226					5.1155 5.1184	9.0579 9.0551		
	B2	HYATT	W-226					5.1205 5.1196	9.0574 9.0547		
		TIMKEN	74525-74850	8.5010 8.5000	4.5000 4.5000	1.8750			8.5020 8.5000		
		ROLLWAY	MF-5226					5.1153 5.1183	9.0600 9.0576		
		N.HOFFMANN	RLS-23-RR					5.0010 5.0005	8.9985 8.9980		
		S.K.F.	22226					5.1155 5.1184	9.0579 9.0551		
	B3	HYATT									
		TIMKEN									
		ROLLWAY									
		N.HOFFMANN	RLT-23½					5.0010 5.0005	9.4985 9.4980		
		S.K.F.	PILLOW BLOCK								
5½"	B1	HYATT	W-220					3.5390 3.9382	7.0886 7.0863		
		TIMKEN	74537-74850	8.5010 8.5000	5.3760 5.3750	1.8750			8.5020 8.5000		
		ROLLWAY	MF-5226					5.1153 5.1183	9.0600 9.0576		
		N.HOFFMANN	RLS-23½-RR					5.5010 5.5005	9.4985 9.4980		
		S.K.F.	22226					5.1155 5.1184	9.0579 9.0551		
	B2	HYATT	W-226					5.1205 5.1196	9.0574 9.0547		
		TIMKEN	74537-74850	8.5010 8.5000	5.3760 5.3750	1.8750			8.5020 8.5000		
		ROLLWAY	MF-5226					5.1153 5.1183	9.0600 9.0576		
		N.HOFFMANN	RLS-23½-RR					5.5010 5.5005	9.4985 9.4980		
		S.K.F.	22226					5.1155 5.1184	9.0579 9.0551		
	B3	HYATT									
		TIMKEN									
		ROLLWAY									
		N.HOFFMANN	RLT-24					5.5010 5.5005	9.4985 9.4980		
		S.K.F.	PILLOW BLOCK								

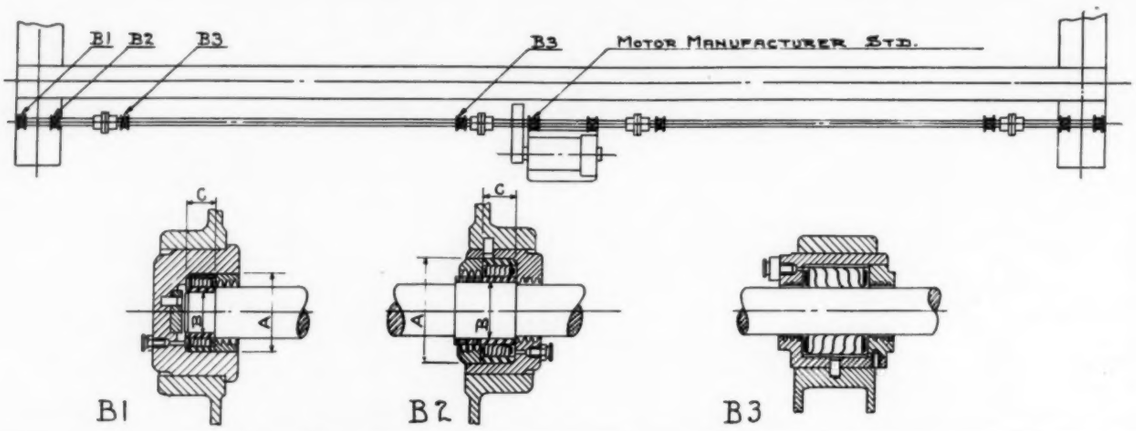
Table - D7b



CLEVELAND CRANE DATA

NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT
3¼"	B1	HYATT	W-213	4.7244	2.5591	2.0625		4.7240 4.7235	4.7244	4.7250 4.7245
		HELIFLEX	RBC-W213	4.7244	2.5590	2.0625		4.7240 4.7235	4.7244	4.7250 4.7245
		ROLLWAY	WD-213	4.7244	2.5590	2.0625		4.7240 4.7235	4.7244	4.7250 4.7245
	B2	HYATT	W-217	5.9055	3.3465	2.7500		5.9060 5.9055	5.9055	5.9075 5.9052
		HELIFLEX	RBC-W217	5.9055	3.3464	2.7500		5.9060 5.9055	5.9055	5.9075 5.9052
		ROLLWAY	W-217	5.9055	3.3464	2.7500		5.9060 5.9055	5.9055	5.9075 5.9052
	B3	HYATT								
		HELIFLEX	RBC-19751	5.5000	3.2500	3.0000		5.5040 5.4960	5.5000	5.5040 5.5000
		ROLLWAY								
3½"	B1	HYATT	W-214	4.9213	2.7559	2.3750		4.9218 4.9213	4.9213	4.9229 4.9224
		HELIFLEX	RBC-W214	4.9213	2.7559	2.3750		4.9218 4.9213	4.9213	4.9229 4.9224
		ROLLWAY	WD-214	4.9213	2.7559	2.3750		4.9218 4.9213	4.9213	4.9229 4.9224
	B2	HYATT	W-218	6.2992	3.5433	2.8125		6.3011 6.2992	6.2992	6.3011 6.2990
		HELIFLEX	RBC-W218	6.2992	3.5433	2.8125		6.3011 6.2992	6.2992	6.3011 6.2989
		ROLLWAY	WD-218	6.2992	3.5433	2.8125		6.3011 6.2992	6.2992	6.3011 6.2989
	B3	HYATT	40010	6.1250	3.5000	4.0000		6.1300 6.1250	6.1250	6.1300 6.1250
		HELIFLEX	RBC-40010	6.1250	3.5000	4.0000		6.1300 6.1250	6.1250	6.1300 6.1250
		ROLLWAY	A-4264	6.1250	3.5000	4.0000		6.1300 6.1250	6.1250	6.1300 6.1250
4"	B1	HYATT	W-216	5.5118	3.1496	2.6250		5.5135 5.5118	5.5118	5.5135 5.5118
		HELIFLEX	RBC-W216	5.5118	3.1496	2.6250		5.5135 5.5118	5.5118	5.5135 5.5118
		ROLLWAY	WD-216	5.5118	3.1496	2.6250		5.5135 5.5118	5.5118	5.5135 5.5118
	B2	HYATT	W-222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
		HELIFLEX	RBC-W222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
		ROLLWAY	WD-222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
	B3	HYATT	40061	6.6250	4.0000	4.0000		6.6300 6.6250	6.6250	6.6300 6.6250
		HELIFLEX	RBC-40061	6.6250	4.0000	4.0000		6.6300 6.6250	6.6250	6.6300 6.6250
		ROLLWAY	A-4364	6.6250	4.0000	4.0000		6.6300 6.6250	6.6250	6.6300 6.6250
4¼"	B1	HYATT	W-217	5.9055	3.3465	2.7500		5.9073 5.9055	5.9055	5.9073 5.9052
		HELIFLEX	RBC-W217	5.9055	3.3464	2.7500		5.9073 5.9055	5.9055	5.9073 5.9052
		ROLLWAY	WD-217	5.9055	3.3464	2.7500		5.9073 5.9055	5.9055	5.9073 5.9052
	B2	HYATT	W-222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
		HELIFLEX	RBC-W222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
		ROLLWAY	WD-222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
	B3	HYATT								
		HELIFLEX	RBC-40072	7.1250	4.2500	4.0000		7.1300 7.1250	7.1250	7.1300 7.1250
		ROLLWAY								
4½"	B1	HYATT	W-218	6.2992	3.5433	2.8125		6.3011 6.2992	6.2992	6.3011 6.2990
		HELIFLEX	RBC-W218	6.2992	3.5433	2.8125		6.3011 6.2992	6.2992	6.3011 6.2989
		ROLLWAY	WD-218	6.2992	3.5433	2.8125		6.3011 6.2992	6.2992	6.3011 6.2989
	B2	HYATT	W-224	8.4646	4.7244	3.8750		8.4669 8.4646	8.4646	8.4669 8.4643
		HELIFLEX	RBC-W224	8.4646	4.7244	3.8750		8.4669 8.4646	8.4646	8.4669 8.4643
		ROLLWAY	WD-224	8.4646	4.7244	3.8750		8.4670 8.4646	8.4646	8.4670 8.4643
	B3	HYATT	40360	7.3750	4.5000	4.0000		7.3800 7.3750	7.3750	7.3800 7.3750
		HELIFLEX	RBC-40360	7.3750	4.5000	4.0000		7.3800 7.3750	7.3750	7.3800 7.3750
		ROLLWAY	A-4564	7.3750	4.5000	4.0000		7.3800 7.3750	7.3750	7.3800 7.3750
5	B1	HYATT	W-220	7.0866	3.9370	3.2500		7.0886 7.0866	7.0866	7.0886 7.0863
		HELIFLEX	RBC-W220	7.0866	3.9370	3.2500		7.0886 7.0866	7.0866	7.0886 7.0863
		ROLLWAY	WD-220	7.0866	3.9370	3.2500		7.0886 7.0866	7.0866	7.0886 7.0863
	B2	HYATT	W-226	9.0551	5.1181	4.2500		9.0571 9.0551	9.0551	9.0571 9.0547
		HELIFLEX	RBC-W226	9.0551	5.1181	4.2500		9.0571 9.0551	9.0551	9.0571 9.0546
		ROLLWAY	WD-226	9.0552	5.1181	4.2500		9.0571 9.0551	9.0551	9.0571 9.0546
	B3	HYATT	40410	7.8750	5.0000	4.0000		7.8800 7.8750	7.8750	7.8800 7.8750
		HELIFLEX	RBC-40410	7.8750	5.0000	4.0000		7.8800 7.8750	7.8750	7.8800 7.8750
		ROLLWAY	A-4664	7.8750	5.0000	4.0000		7.8830 7.8800	7.8750	7.8830 7.8800
5½"	B1	HYATT	W-222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
		HELIFLEX	RBC-W222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
		ROLLWAY	WD-222	7.8740	4.3307	3.5000		7.8762 7.8740	7.8740	7.8762 7.8737
	B2	HYATT	W-228	9.8425	5.1181	4.7500		9.8450 9.8425	9.8425	9.8450 9.8421
		HELIFLEX	RBC-W228	9.8425	5.1181	4.7500		9.8450 9.8425	9.8425	9.8450 9.8421
		ROLLWAY	WD-228	9.8426	5.1181	4.7500		9.8451 9.8426	9.8426	9.8451 9.8419
	B3	HYATT								
		HELIFLEX	RBC-40411	8.3750	5.5000	4.0000		8.3800 8.3750	8.3750	8.3800 8.3750
		ROLLWAY								

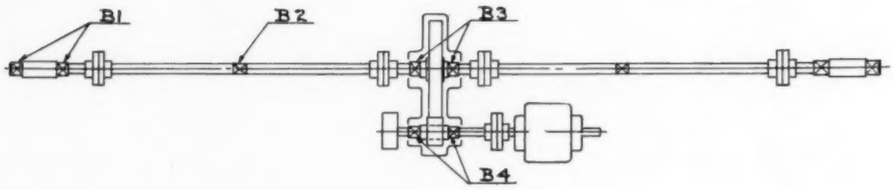
Table --- D8



P. & H. Co. Crane Data

NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT	
3½"	B1	HYATT	219	6.6929	3.7402	2.1875	4.5000	3.7414 3.7412	6.6945 6.6926		
	B2	HYATT	214	4.9213	2.7559	1.6250	3.3125	2.7572 2.7566	4.9229 4.9211		
	B3	HYATT	40010			4.0000		3.5000 3.4990	6.1250 6.1250		
4"	B1	HYATT	220	7.0866	3.9370	2.3125	4.7500	3.9385 3.9380	7.0882 7.0863		
	B2	HYATT	216	5.5118	3.1496	1.8125	3.7500	3.1515 3.1504	5.5138 5.5118		
	B3	HYATT	40061			4.0000		4.0000 3.9960	6.6299 6.6259		
4½"	B1	HYATT	222	7.8740	4.3307	2.5625	5.2500	4.3327 4.3320	7.8763 7.8737		
	B2	HYATT	218	6.2992	3.5433	2.0625	4.2500	3.5454 3.5449	6.3011 6.2992		
	B3	HYATT	40360			4.0000		4.0000 3.9960	7.3800 7.3750		
5"	B1	HYATT	224	8.4646	4.7244	2.8125	5.6250	4.7271 4.7256	8.4670 8.4642		
	B2	HYATT	219	6.6929	3.7402	2.1875	4.5000	3.7414 3.7412	6.6945 6.6926		
	B3	HYATT	40410			4.0000		5.0000 4.9950	7.8800 7.8750		

Table - D9



Shepard-Niles Crane Data

NOMINAL SHAFT DIA.	BEARING LOCATION	BEARING MANUFACTURER	BEARING SIZE	ROLLER OR BALL BEARING DIMENSIONS A	B	C	D	SHAFT FIT	HOUSING BORE	HOUSING FIT	
2"	B1	HYATT	W-211					2.1667	3.5384		
	B2	HYATT	18420					2.1661	3.5362		
	B3	HYATT	213					2.0000	3.5030		
	B4	HYATT	211					1.9970	3.5000		
2½"	B1	HYATT	W-213					2.5605	4.7260		
	B2	HYATT	49573					2.5599	4.7243		
	B3	HYATT	213					2.5605	4.7260		
	B4	HYATT	211					2.5599	4.7243		
3"	B1	HYATT	W-216					3.1667	5.3384		
	B2	HYATT	49725					3.1661	5.3362		
	B3	HYATT	216					3.1513	5.5135		
	B4	HYATT	215					3.1506	5.5116		
4"	B1	HYATT	W-222					4.3328	7.8762		
	B2	HYATT	40061					4.3320	7.8737		
	B3	HYATT	216					3.1513	5.5135		
	B4	HYATT	215					3.1506	5.5116		

Table - D10

Tabulation Of Bearing Data

Application Of Anti-Friction Bearing On Rolling Mill Roll Necks

Mill Size & Type	Arrg't.	Where Operating	Loc. Of Bearing	Roll Body Dia	Roll Body L	Roll Neck Dia	Roll Neck L	Bearing Rating At 100 RPM Radial	Bearing Rating At 100 RPM Axial	Roller Bearing Number	Roller Bearing Mf'g.
Sheet & Tin Plate Mills											
16" Sheet Mill	4 High	Amer. Sheet & Tin Plate Co McKeesport, Pa.	Working Rolls	16"	55"	9¾"	14"	314,000		CS-31041	Rollway
16" Sheet Mill	4 High	Amer. Sheet & Tin Plate Co. McKeesport, Pa.	Backing Rolls	34"	55"	20"	23½"	1120,000		CS-31042	Rollway
16" Cold Sheet	4 High	Amer. Sheet & Tin Plate Co. Farrel, Pa.	Backing Rolls	48"	84"	29½"	27"	2384,900	968,600	532296 532445 532446	Timken
26" Cold Sheet	2 High	Amer. Rolling Mill Co. Ashland, Ky.	Working Rolls	26"	58	16"	12½"	317,200	101,300	911601 912400 912401	Timken
Strip & Hoop Mills											
4½ Cold Strip	4 High	Thomas Steel Co Warren Ohio	Backing Rolls	16"	12"	7"	4⅞"	57,120	38,000	780702 781400	Timken
6" Strip Mill	4 High	Central Alloy Steel Co Canton, Ohio	Working Rolls	6"	16"	3"	7"	28,000		CS-31099	Rollway
5¾" Strip Mill	4 High	Acme Steel Co Chicago, Ill	Working Rolls	19"	18"						Rollway
7½" Strip Mill	4 High	Thomas Steel Co Warren, Ohio	Working Rolls	19"	24"	8"	7¼"	152,000		CS-31064	Rollway
8½" Narrow Strip	2 High	Sharon Steel Hoop Co. Sharon, Pa.	Working Rolls	8½"		5¼"	7¼"	66,600		CS-21063	Rollway
10" Hot Strip		Amer. Steel & Wire Co. Cuyhoga Falls, Ohio	Working Rolls					39,200	12,065	C-11124	Timken
10½" Narrow Strip	2 High	Sharon Steel Hoop Co Sharon, Pa.	Working Rolls	10½"	10"	6¼"	10"	100,000		CS-31046	Rollway
10½" Strip Mill	2 High	Sharon Steel Hoop Co Sharon, Pa.	Working Rolls	10½"	18"	6¼"	5"	77,500		CS-31046	Rollway
11" Hot Strip	4 High	Laclede Steel Co St. Louis, Mo.	Backing Rolls	22"	24"	8½"		360,000		CS-31077	Rollway
11" Hot Strip	4 High	Laclede Steel Co St. Louis, Mo.				10½"	5¾"	180,200		CS-31031	Rollway
12½" Narrow Strip	2 High	Sharon Steel Hoop Co Sharon, Pa.	Working Rolls	12½"	18"	8"	11"	200,000		CS-31064	Rollway
14" Strip Mill	4 High	Amer. Rolling Mill Co. Butler, Pa.	Working Rolls	30"	42"	8"	7¼"	152,000		CS-31064	Rollway
18" Hot Strip 1 Stand	4 High	Amer. Rolling Mill Co. Middletown, Ohio	Backing Rolls	40"	58"	21.995	18"	1243,300	422,800	327221 327355 327356	Timken
18" Hot Strip 2 Stands	4 High	Amer. Rolling Mill Co. Middletown, Ohio	Backing Rolls	40	58"	21.995	18"	1243,300	422,800	327221 327355 327356	Timken
18" Cold Strip	2 High	Amer. Steel & Wire Co Cuyhoga Falls, Ohio	Working Rolls			10"	4½"	40,800	22,600	251000 251575	Timken
60" Hot Strip 3 Stand	4 High	Wheeling Steel Corp Wheeling, W. Va.	Working Rolls	60"		14"	5"	53,000	38,000	231401 232025	Timken
Cold Strip	4 High	Amer. Rolling Mill Co. Ashland, Ky.	Working Rolls			17.995	16"	754,820	247,000	671795 672873 672874	Timken
Hot Strip 3 Stands	4 High	Amer. Sheet & Tin Plate Co. Gary, Ind.	Backing Rolls			17.384	20¾"	1034,300	380,300	425178 425179 425335	Timken
Cold Strip Cluster Mill	4 High	Amer. Steel & Wire Co. Cuyhoga Falls, Ohio	Working Rolls			12"	11¼"	242,400	81,000	941200 941250 941251	Timken
Hot Strip	4 High	Laclede Steel Co. Alton, Ill.	Backing Rolls			10"	11¾"	138,860	38,480	551000 551700 551701	Timken
Cold Strip 4 Stands	4 High	Wheeling Steel Corp. Yorkville, Pa.	Backing Working			17.004	10"	418,000 65,200	257,640 43,600	328173 328264 328265	Timken
Bar-Rod & Wire Mills											
8" Rod Nut Stock	2 High	Amer. Steel & Wire Co. Cleveland, Ohio	Working Rolls	8"		4⅞"	7"	41,000		CS-31036	Rollway
10" Rod Nut Stock	2 High	Amer. Steel & Wire Co Cleveland, Ohio	Working Rolls	10"		6"	5"	72,800		CS-31034	Rollway
10" Rod Mill	2 High	Canadian Steel & Tube Products Co.		9¾" 9¾"	10" 10"	5½" 5½"				I-28805 I-37603 I-34105-K	S.K.F.
10" Rod Mill	2 High	Timken Steel & Tube Co Canton, Ohio				5½"	5"	14,000	5,400	73550 73875 73876	Timken
21" Bar Mill 4 Stands	2 High	Great Lakes Steel Co. Ecorse, Mich.	Working Rolls			11"	13¾"	203,424	65,973	722111 722185 722186	Timken
18" Bar Mill 4 Stands	3 High	Great Lakes Steel Co. Ecorse, Mich.	Working Rolls			10¼"	12½"	138,860	38,480	551027 551662 551663	Timken
18" Bar Mill 4 Stands	2 High	Great Lakes Steel Co. Ecorse, Mich.	Working Rolls			10¼"	12½"	138,860	38,480	551027 551662 551663	Timken
22" Bar Mill 2 Stands	3 High	Timken Steel & Tube Co. Canton, Ohio	Working Rolls			12"	9½"	94,280	29,600	751200 751750 751751	Timken
28" Bar Mill	3 High	Timken Steel & Tube Co. Canton, Ohio	Roll Necks			16"	12½"	317,200	101,300	911601 912400 912401	Timken

TABLE-E1

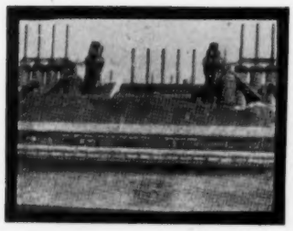
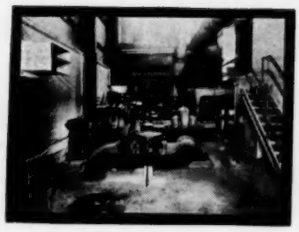
Mill Size & Type	Arrg't.	Where Operating	Loc Of Bearing	Roll Body Dia	Roll Body L	Roll Neck Dia	Roll Neck L	Bearing Rating at 100 RPM Radial	Bearing Rating at 100 RPM Axial	Roller Bearing Number	Roller Bearing M'f'g.
Beam-Structural & Merchant Mills											
52" Beam Mill Universal 3 Stands		Carnegie Steel Co Munhall, Pa.	Vertical Rolls			12½"	16½"	1030,000	239,000	141250 142350 142550 142650	Timken
52" Beam Mill Universal 3 Stand		Illinois Steel Co. So. Chicago, Ills.	Vertical Rolls			12½"	16½"	1030,000	239,000	141250 142651 142652	Timken
Structural Mill Feed & Back Stands		Kalman Steel Co. Chicago, Ills.	Working Rolls L.H.			5⅜"	1⅞"	54,445	8,845	74537 74850	Timken
Structural Mill Feed & Back Stands		Kalman Steel Co. Chicago, Ills	Working Rolls R.H.			4½"	1⅞"	4,825	6,690	71450 71750	Timken
Structural Mill Slitting Stand	2 High	Kalman Steel Co Chicago, Ills	Upper L.H. Lower L.H			8"	6¼"	65,200	43,600	420800 421450	Timken
Structural Mill Slitting Stand	2 High	Kalman Steel Co Chicago, Ills.	Upper R.H Rolls			8"	2½"	14,570	25,420	93800 93125	Timken
Structural Mill Slitting Stand	2 High	Kalman Steel Co Chicago, Ills.	Lower R.H Rolls			5½"	2⅝"	10,885	14,770	99550 99100	Timken
16" Merchant 5 Stands	2 High	Timken Steel & Tube Co Canton, Ohio	Working Pinion End Opposite End			9"	10"	78,600	21,640	130850 130900 131400 131401	Timken
18" Merchant 3 Stands	2 High	Timken Steel & Tube Co Canton, Ohio	Working Pinion End Opposite "			10¼"	10"	98,700	32,400	220975 221025 221575 221576	Timken
Vertical Finishing Mill		Timken Steel & Tube Co Canton, Ohio	Roll Necks			5½"	5"	14,900	5,400	73550 73875 73876	Timken
26 Rerolling Mill 2 Stands	2 High	Timken Steel & Tube Co Canton, Ohio	Roll Necks			14"	10¼"	106,000	38,900	231401 232025 232026	Timken
Hot-Sizing & Cluster Mills											
18" Hot Mill 6 Stands	4 High	Great Lakes Steel Co Ecorse, Mich.	Backing Rolls	37"	38"	18"	13½"	841,100	471,300	525182 525320	Timken
18" Hot Mill 6 Stands	4 High	Great Lakes Steel Co Ecorse, Mich.	Working Rolls			10½"	10¼"	98,572	33,000	275106 275160 275161	Timken
24" Hot Plate Mill 6 Stands		Illinois Steel Co So. Chicago, Ills.	Backing Rolls	52"	96"	29½"	29"	3235,000	1008,200	690296 690465 690466	Timken
60" Hot Mill 6 Stands	4 High	Wheeling Steel Corp Wheeling, W. Va	Backing Rolls			23"	21¼"	1520,600	419,900	662301 663550 663551	Timken
60" Hot Mill 6 Stands	4 High	Wheeling Steel Corp Wheeling, W. Va	Working Rolls			12"	4¾"	25,900	18,950	111201 111700	Timken
Sizing Mill 5 Stands		Babcock & Wilcox Co Bayonne, N.J.	Working Rolls			9"	4¾"	39,300	21,640	130900 131400	Timken
14" Mill 2 Cluster		International Nickel Co Huntington, W. Va	Backing Rolls	24"	42"	13½"	11½"	278,400	77,150	971352 972100 972102	Timken
Copper-Bronze-Aluminum Rolling Mills											
7" Copper & Brass	4 High	Mich. Copper & Brass Co Detroit, Mich	Working Rolls	7"	18"	6½"	10"	21,000		MCS-31089	Rollway
7" Copper & Brass	4 High	Rome Brass & Copper Co Rome, N.Y	Working Rolls	19"	18"	6½"	10	21,000		CS-31089	Rollway
10" Bronze Strip	2 High	Cleveland Graphite Bronze Co Cleveland, Ohio		10"		6"	9"	99,200		CS-31034	Rollway
14" Copper & Brass	4 High	Dallas Brass & Copper Co Chicago, Ills	Working Rolls	28"	24"	6½"	10"	21,000		CS-31089	Rollway
14" Copper & Brass	4 High	Taunton-New Bedford Copper Co New Bedford, Conn	Working Rolls	28"	30"	6½"	10"	21,000		CS-31089	Rollway
14" Copper Sheet	Cluster	New Haven Copper Co Seymour, Conn.	Backing Rolls	25"	48"	14½	18¼	900,000		CS-31013	Rollway
14" Aluminum Rod Finishing Mill		Aluminum Co. of Canada		15"	12"	7¼"				22240 I-34110	S.K.F
15" Aluminum Flat Wire Mill Cold	2 High	Aluminum Co of Canada		15"	12"	8"				I-26308	S.K.F.
Brass Rolling Mill Cold	2 High	Bridgeport Brass Co.		12½"	14"	9¼"				I-26306	S.K.F.
	4 High	American Brass Co Waterbury, Conn.				9¾"	9"	236,000		CS-31041	Rollway

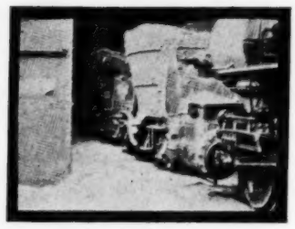
TABLE-E2

Mill Size & Type	Arr'g't.	Where Operating	Loc. of Bearing	Roll Body Dia	Roll Body L	Roll Neck Dia	Roll Neck L	Bearing Rating at 100 R.P.M. Radial	Bearing Rating at 100 R.P.M. Axial	Roller Bearing Number	Roller Bearing Mf'g.
Cold Rolling & Steckel Mills											
7" Cold Rolling	4 High	Thomas Steel Co. Warren, Ohio	Backing Rolls	19"	24"	10"	11¾"	138,860	35480	551000 551700 551701	Timken
10" Cold Rolling	2 High	Thomas Steel Co. Warren, Ohio	Working Rolls			5"	5½"	19,580	12,060	95499 95925	Timken
10" Cold Rolling	2 High	Amer. Steel & Wire Co.		10⅝"	18½"	6¾"				7813 6228 X 537	S.K.F.
10" Cold Rolling	2 High	Amer. Steel & Wire Co.		8⅜"	8"	5"				I-70176 6221	S.K.F.
14" Cold Rolling 4 Stands	4 High	Amer. Steel & Wire Co. Cleveland, Ohio	Backing Rolls	25"	16"	11½"	11¼"	320,600	211,145	790117 790220	Timken
16" Cold Rolling	2 High	Thomas Steel Co. Warren, Ohio	Working Rolls			8"	12⅞"	130,400	43,600	420800 421450 421451	Timken
16½" Cold Rolling 4 Stands	4 High	Amer. Steel & Wire Co. Cleveland, Ohio	Backing Rolls	33"	26"	16½"	14"	571,040	339,220	123167 123290	Timken
16½" Cold Rolling 4 Stands	4 High	Amer. Steel & Wire Co. Cleveland, Ohio	Working Rolls			7"	2½"	13,035	20,340	94700 94113	Timken
14" Cold Rolling 4 Stands	4 High	Amer. Steel & Wire Co. Cleveland, Ohio	Working Rolls			5¾"	2¼"	8,140	71,990	82576 82950	Timken
Cold Rolling		Athenia Steel Co.		6¾"	4¾"	3"				22315	S.K.F.
Cold Rolling		Athenia Steel Co.		14½"	10"	8"				22322	S.K.F.
2¼" Steckel	4 High	Cold Metal Process Co. Youngstown, Ohio	Backing Rolls	20"	7½"	6¼"	5"	77,500		CS-31046	Rollway
3" Steckel	4 High	Cold Metal Process Co Youngstown, Ohio	Backing Rolls	24"	18"	9¾"	9"	236,000		CS-31041	Rollway
				13"	24"	8¼"				I-70152 6234 X	S.K.F.
Cold Rolling	2 High	Wheeling Steel Corp. Steubenville, Ohio	Woring Rolls			14½"	10"	289,800	172,379	321146 321245	Timken
				10⅝"	10¼"	6¾"				I-70177 6228	S.K.F.
				10⅝"	18"	6¾"				I-70177 6228	S.K.F.
				16"	24"	10¼"				I-70191 I-70193	S.K.F.
Tube Piercing-Reeling & Skelp Mills											
1929 Tube Piercing		Globe Steel Tube Co		27"		8.66"				22344X	S.K.F.
*4 Lap Weld Tube Mill		National Tube Co Gary, Ind.	Roll Necks			7"	9 3/16"	60,800	18,250	280700 281200 281201	Timken
34" Tube Piercing Mill		Timken Steel & Tube Co Canton, Ohio	Working Rolls			12"	5 7/16"	121200	81,000	941102 941202 941950	Timken
34" Tube Piercing Mill		Timken Steel & Tube Co. Ganbrinus, Ohio	Working Rolls			12"	5 7/16"	121200	81,000	941102 941202 941950	Timken
Seamless Tube Piercing		Timken Steel & Tube Co. Canton, Ohio	Roll Necks Drive End			7"	9 3/16"	60,800	18,250	280700 281200 281201	Timken
Seamless Tube Piercing		Timken Steel & Tube Co Canton, Ohio	Roll Necks Opposite End			6¼"	9 3/16"	60,800	18,250	280625 281200 281201	Timken
Tube Reducing 9 Stands		Timken Steel & Tube Co. Canton, Ohio	Roll Necks			5⅞"	5¼"	10885	14,770	99587 99100	Timken
*3 Disc Type Piercing Mill		Babcock & Wilcox Tube Co. Beaver Falls, Pa.	Working Piercing End			14½"	13½"	360300	124480	181452 182350 182351	Timken
#3 Disc Type Piercing Mill		Babcock & Wilcox Tube Co. Beaver Falls, Pa.	Working Opposite End			9½"	4 5/8"	71231	222,550	390095 390200	Timken
1928 Reeling Mill		Globe Steel Tube Co		28"		7.48"				22338	S.K.F.
Reeling Mill		Globe Steel Tube Co		24"		8"				22336	S.K.F.
13" Skelp Mill	4 High	National Tube Co.	Backing Rolls	26"	20"	10¼"				I-26315	S.K.F.

Note:-
Rating For Timken Bearing At 500 R.P.M.
For Rating At 100 R.P.M. Multiply By 1.665

Table-E3



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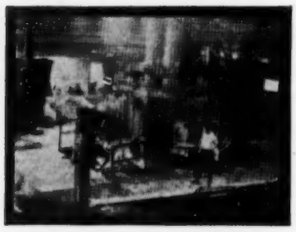

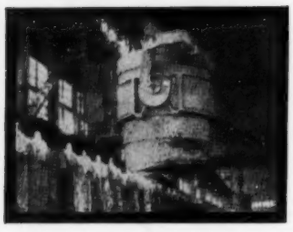

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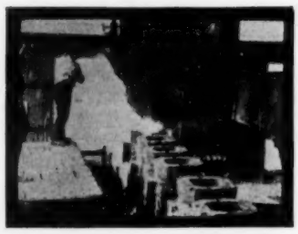

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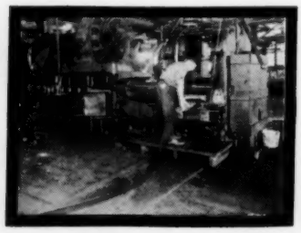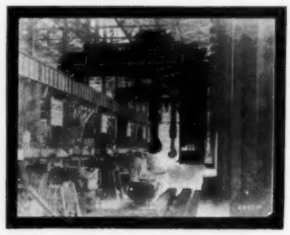
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